From: Rochlin, Kevin
Sent: Wednesday, January 22, 2014 9:07 AM
To: 'Bill Bacon'
Subject: RE: EMF/FMC documents
Attachments: Appendix O Attachment O-2.pdf; 1986 06-07 An Aerial Radiological Survey of Pocatello and Soda Springs.pdf

Categories: 11-19 to 1-10 2014

Bill,

These may be what you are thinking of.

Kevin

From:

Kevin Rochlin | **Superfund Remedial Project Manager**
U.S. Environmental Protection Agency | **Region 10**
Office of Environmental Cleanup
1200 6th Avenue, Suite 900, ELC-111 | **Seattle, WA 98101**
(206) 553-2106
(206) 553-0124 (fax)
rochlin.kevin@epa.gov

From: Bill Bacon [mailto:bbacon@sbtribes.com]
Sent: Friday, November 22, 2013 8:52 AM
To: Rochlin, Kevin
Subject: RE: EMF/FMC documents

Kevin:

What I am trying to find is the gamma radiation study at the FMC-OU slag pile. Kelly Wright thought it was done in the 1990's. The second document was from 1996 amending the 1995 BERA. Thanks, Bill

---

From: Rochlin, Kevin [mailto:rochlin.kevin@epa.gov]
Sent: Thursday, November 21, 2013 5:14 PM
To: Bill Bacon
Subject: RE: EMF/FMC documents

Got into the system. Here is the first document.

Kevin

From:

Kevin Rochlin | **Superfund Remedial Project Manager**
U.S. Environmental Protection Agency | **Region 10**
Office of Environmental Cleanup
1200 6th Avenue, Suite 900, ELC-111 | **Seattle, WA 98101**
(206) 553-2106
(206) 553-0124 (fax)
rochlin.kevin@epa.gov

From: Bill Bacon [mailto:bbacon@sbtribes.com]
Sent: Thursday, November 21, 2013 12:49 PM
To: Rochlin, Kevin
Subject: RE: EMF/FMC documents

Ok, thanks, I can wait. Bill

From: Rochlin, Kevin [mailto:rochlin.kevin@epa.gov]
Sent: Thursday, November 21, 2013 1:12 PM
To: Bill Bacon
Subject: RE: EMF/FMC documents

Bill,

Our document management system is currently offline. I do not have the ability to get the documents until next week.

Kevin

____

From:

Kevin Rochlin | **Superfund Remedial Project Manager**
U.S. Environmental Protection Agency | **Region 10**
Office of Environmental Cleanup
1200 6th Avenue, Suite 900, ELC-111 | **Seattle, WA 98101**
(206) 553-2106
(206) 553-0124 (fax)
rochlin.kevin@epa.gov

From: Bill Bacon [mailto:bbacon@sbtribes.com]
Sent: Thursday, November 21, 2013 12:10 PM
To: Rochlin, Kevin
Subject: RE: EMF/FMC documents

Kevin:

Sorry to bother you but our folks indicated there was a radionuclide study done at the FMC-OU in the 1990's and a 1996 BERA. If you could forward those to me I would appreciate it. Thanks, Bill

---

From: Rochlin, Kevin [mailto:rochlin.kevin@epa.gov]
Sent: Monday, September 30, 2013 11:57 AM
To: Bill Bacon
Cc: Ordine, Charles
Subject: RE: EMF/FMC documents

Bill,

Attached are the documents you requested. The dates did not match, but the names did. Let me know if these are not the correct documents.

Kevin

____

From:

Kevin Rochlin, Project Manager
Office of Environmental Cleanup
United States Environmental Protection Agency
Region 10
Suite 900
1200 6th Avenue
Seattle, WA 98101
(206) 553-2106
(206) 553-0124 (fax)
rochlin.kevin@epa.gov

From: Bill Bacon [mailto:bbacon@sbtribes.com]
Sent: Monday, September 30, 2013 8:53 AM
To: Rochlin, Kevin

Subject: EMF/FMC documents

Kevin:

I am the General Counsel for the Shoshone-Bannock Tribes. Could you please forward me the following:

1. Appendix J to the May 2009 SRI
2. Appendices D and E to the November 2009 Addendum to the SRI

Thanks, Bill 208-478-3822

Air & Toxics Divisio
EPA Region 10
20.6

EG&G
ENERGY MEASUREMENTS

EPA-8613

EMCSF
2/1/87

AN AERIAL RADIOLOGICAL SURVEY OF

POCATELLO AND SODA SPRINGS, IDAHO

AND SURROUNDING AREA

DATE OF SURVEY: JUNE - JULY 1986

FEBRUARY 1987

LAS VEGAS OPERATIONS
P.O. BOX 1912, LAS VEGAS, NEVADA 89125

TABLES

1. INTRODUCTION

Three aerial radiological surveys were conducted during the period 16 June through 15 July 1986 over the towns of Pocatello, Soda Springs, and Fort Hall, Idaho and the surrounding areas. The surveys were performed for the United States Environmental Protection Agency (EPA), Office of Radiation Programs, by the United States Department of Energy's (DOE) Remote Sensing Laboratory (RSL), utilizing the Aerial Measuring System (AMS) operated by EG&G Energy Measurements, Inc. (EG&G/EM), Las Vegas, Nevada. This work was completed in cooperation with a study by the EPA to conduct a dose assessment of human radiation exposure for industrial sources in Pocatello and Soda Springs, Idaho.

The aerial surveys were performed to document the natural terrestrial radiological environment of the three localities and to map the spatial extent and degree of contamination due to phosphate milling operations. The results of these surveys will be used for planning ground-based measurements in addition to being incorporated into the dose assessment document.

An important characteristic of airborne radiation detection systems is that the results are averages over large areas (several hectares) as compared to the small area covered by ground-based measurements. This has three significant consequences. First, an airborne radiation detection system can rapidly obtain measurements which are much more representative of an area-averaged value than hundreds, or perhaps thousands, of time-consuming ground-based measurements. Second, the intensity of localized sources or anomalies may be significantly underestimated because of this large-area averaging. This effect becomes increasingly pronounced as the spatial extent of the source becomes small with respect to the large area averaged by the airborne detection system. Finally, airborne detection systems "blur" the apparent edges of small anomalies. That is, the airborne system can "see," to some degree, anomalies that are off to the side of the aircraft in addition to those directly below. Therefore, ground-based measurements may be required to accurately measure the intensity of localized sources and to define the exact boundary of a small radiation anomaly.

2. SURVEY AREAS

The primary aerial survey sites of Pocatello and Soda Springs, located in the southeastern corner of the state of Idaho, were selected for this study by the EPA. The selection criteria were based on the presence of elemental phosphorus plants and the long-term, widespread use of slag material from the plants throughout the area.

The aerial survey of the Pocatello site, which included portions of both Bannock and Power Counties, covered an area of approximately 231 square kilometers (89 square miles). Included in the survey area were the towns of Pocatello and Chubbuck and surrounding areas, the FMC and Simplot plants, and the municipal airport. FMC is an elemental phosphorus plant, while Simplot is a phosphate fertilizer plant.

The Soda Springs site, located in Caribou County, covered an area of approximately 43 square kilometers (16.6 square miles) and included the town of Soda Springs and the Monsanto elemental phosphorus plant located just north of town. In addition, a small phosphate fertilizer plant and the Kerr-McGee vanadium plant, which processes phosphate materials and/or by-products, were also included.

A small survey over the town of Fort Hall, Idaho was also included in addition to the two primary sites of Pocatello and Soda Springs. Fort Hall is located in Bannock County on the Shoshone-Bannock Indian Reservation, approximately 19 kilometers (12 miles) north of Pocatello. This secondary site was selected as a background and system check area because of the limited use of slag material in the vicinity. The survey covered approximately 12.2 square kilometers (4.9 square miles) and was centered over the major portion of the settlement.

3. NATURAL BACKGROUND RADIATION

Natural background radiation originates from naturally-occurring radioactive elements present in the earth (terrestrial radiation) and radiation entering the earth's atmosphere from space (cosmic radiation).

Natural terrestrial gamma radiation originates primarily from the uranium and thorium decay chains and radioactive potassium. The natural terrestrial radiation levels depend upon the type of soil and bedrock immediately below and surrounding the point of measurement. Within cities, the levels are also dependent on the nature of the street and building materials. Local concentrations of these naturally-occurring nuclides produce exposure rate levels at the surface of the earth generally ranging from 1 to 20 microroentgens per hour (μR/h). The highest levels within the United States are normally found in the western states, primarily on the Colorado Plateau, as a result of higher uranium and thorium concentrations in surface minerals.

The uranium and thorium decay chains include radon--a radioactive, chemically inert gas--which diffuses through the soil and into the atmosphere. The rate of diffusion is highly variable and the atmospheric distribution of radon can be complex due to a variety of factors. Thus, the magnitude of the background radiation contributed by airborne radon and its daughters depends on the meteorological conditions, the mineral composition and permeability of the soil, as well as other physical conditions existing at each location at a particular time. Typically, radon contributes from 1 to 10 percent of the natural external background radiation exposure.

Cosmic rays, the space component, interact in a complex manner with elements of the earth's atmosphere and the soil. These interactions produce an additional natural source of ionizing radiation. Radiation levels due to cosmic rays vary with elevation (altitude) and slightly with geomagnetic latitude. Typical values range from 3 μR/h at sea level in Florida to 12 μR/h at an altitude of 3 kilometers (10,000 feet) in Colorado (Reference 1).

4. SURVEY EQUIPMENT AND PROCEDURES

The aerial measurement system, comprised of a radiation detector package and a specialized data acquisition and recorder system (REDAR IV*), was mounted on board a high-performance helicopter (Messerschmitt-Bolkow-Blohm BO-105). The detector package consisted of an array of 20 12.7-cm diameter by 5-cm thick (5-in. by 2-in.) sodium iodide (thallium-activated), NaI(Tl), scintillation detectors. This type of detector is particularly sensitive to gamma radiation.

*Radiation and Environmental Data Acquisition and Recorder system, Model IV.

The detector array was distributed equally between two cargo pods that were mounted on the landing skids of the helicopter. Signals from 19 of the detectors were summed to produce a single gamma spectrum with high sensitivity (i.e., able to detect low background levels of radiation). The remaining single detector was used to provide a gamma spectrum with less sensitivity for use in areas exhibiting greatly enhanced levels of radiation. Both spectra were simultaneously acquired and recorded which greatly extended the count rate operating range of the data acquisition system. This dual spectral capability also made it possible to conduct post-flight analyses which ensured that the system was functioning properly and no system failures had occurred during data collection flights, thus providing data integrity safeguards.

The REDAR IV system acquired, monitored, displayed, and recorded all survey data for each second of real time. The data stored on magnetic tape consisted of the dual gamma spectral data, as mentioned previously, and environmental data such as outside air temperature and absolute barometric pressure. Also included were positional data derived from a UHF radio ranging system and a radar altimeter. The REDAR IV system processed this positional data in real time to provide a navigational display for the helicopter pilot.

Each area was surveyed with a series of predetermined parallel lines spaced 76 meters (250 feet) apart and flown at a mean altitude of 46 meters (150 feet) above ground level (AGL). This procedure was chosen to achieve the most sensitive detector platform possible while still maintaining a safe flight configuration.

Detector background due to natural non-terrestrial radiation sources on board the aircraft, airborne radon, and cosmic rays was estimated from multi-altitude flights over a land test line located within the survey area and a water test line adjacent to the survey area. Variations in the radon contributions and soil moisture attentuation were monitored by repeating measurements at survey altitude over the land and water test lines before and after each flight.

More detailed discussions of the systems and procedures employed during aerial survey operations can be found in separate publications (References 2, 3 and 4).

5. DATA PROCESSING PROCEDURES

The data recorded on magnetic tape during the survey were processed with the Radiation and Environmental Data Analyzer and Computer (REDAC) system. This system consisted of a computer analysis laboratory mounted in a mobile van. An extensive inventory of software routines and supporting hardware was available for detailed data analysis. The data were processed during the actual survey period to assure complete coverage and data acquisition integrity, and to provide preliminary results as soon as possible. After completion of the surveys, the final data analysis was accomplished in Las Vegas using the RSL computer system.

For this series of surveys, the data analyses were directed toward producing two specific results: (1) a total terrestrial gamma radiation exposure rate contour map of each of the survey sites, and (2) the identification of anomalous areas above typical background, specifically those associated with the phosphate industry.

The principal representation of the survey results are isoradiation contour maps of exposure rate due to terrestrial gamma ray sources. Exposure rate contours were derived from gross count rate numbers which refer to integral count rates in that portion of the gamma ray energy spectrum between 0.05 and 3.00 MeV. Exposure rate isoradiation contours were constructed by plotting the processed radiation data as a function of position. The values reported represent averages over a large area (several hectares) and are expressed in microroentgens per hour (μR/h) at 1 meter above ground level. When comparing aerial survey results with ground-based measurements, it is important to note that 1 second of aerial survey data covers an area several thousand times larger than that measured by a single hand-held survey instrument 1 meter above ground level and several million times larger than a single soil sample. For large areas with slowly varying activity, such as typical natural background radiation, the agreement between ground-based measurements and those inferred from aerial data is generally quite good. Because of the large-area averaging property of the airborne system, the radiation from small, localized anomalies will be averaged over a larger area indicating a lower activity than actually exists at the ground surface. For these situations, ground measurements will not agree very well with the aerial results. The aerial data, therefore, serve to identify the existence of anomalies, but ground surveys are required for an accurate definition of the spatial extent and intensity of identified anomalies.

The terrestrial count rate is determined by subtracting estimates of the aircraft, radon, and cosmic background contributions to the system from the gross count rate measured each second at the survey altitude. The net count rates are then converted to exposure rates by using a predetermined conversion factor. This conversion factor, determined from years of study at a calibration range, assumes a uniformly distributed source covering an area which is large compared to the detector field-of-view (approximately 200 to 300 meters in diameter at the survey altitude of 46 meters). For a limited source distribution which is small compared to the detector system field-of-view, it is necessary to modify or correct the exposure rate values presented in the Results section by using the information in Table 1, provided that the area of distribution or boundaries of the source are known. Therefore, actual exposure rate values could be one to two orders of magnitude higher than those reported for an area which contains a small localized source (less than 25 meters in diameter).

Table 1. Correction Factors Versus Area of Source for Exposure Rate Data

Source Diameter (meters)	Correction Factor
10	100
25	10
50	6.5
100	2.5
200	1.2
300	1.0
>300	1.0

Anomalous or non-natural gamma sources can be found from increases in the total terrestrial gamma exposure rate data over typical background exposure rates. However, subtle anomalies are difficult to find using the exposure rate data in areas where the magnitude of the exposure rate is variable due to geologic or ground cover changes (i.e., changes in natural background radiation). Data reduction procedures, which exploit variations in spectral shape, were used to increase the aerial system's sensitivity to anomalous gamma emitters. To identify anomalous areas above typical background radiation, specifically those associated with the phosphate industry, an alternate analysis procedure was applied to the data.

This alternate procedure took into account the fact that phosphate ore, which occurs in nature, contains varying concentrations of elements from the uranium and thorium decay chains. In processing ore for elemental phosphorus and/or fertilizer, there are by-products in the form of slag that further concentrate these elements. As stated previously, elements of the uranium and thorium decay chains also occur in nature in areas that have no association with phosphate ore and/or slag. One of the more abundant daughter products in the uranium decay chain in phosphate slag is bismuth-214 (Bi-214). EG&G/EM has found from experience that the energetic gamma ray at 1.76 MeV from Bi-214 is found most readily in a search of the data for the presence of phosphate slag.

Therefore, the method chosen extracted and mapped only the net counts due to excess Bi-214. This procedure results in an enhanced representation of the spatial distribution of the isotope of concern which is relatively free from distortions due to variations in natural background radiation. Variations in background occur because soil is not homogeneous; it contains potassium, uranium, and thorium and their daughter products in varying amounts. It should be noted that only the excess bismuth is mapped in the survey area utilizing this procedure. There is no way to determine if that excess is solely associated with phosphate slag or some other material with higher than normal

EG&G ENERGY MEASUREMENTS

EPA-8613
February 1987

AN AERIAL RADIOLOGICAL SURVEY OF POCATELLO AND SODA SPRINGS, IDAHO AND SURROUNDING AREA

DATE OF SURVEY: June-July 1986

H. A. Berry
Project Scientist
Nuclear Radiation Department

The DOE Remote Sensing Laboratory
Operated for the U.S. Department of Energy by
EG&G Energy Measurements, Inc.
Las Vegas, Nevada

Reviewed By

Harvey W. Clark Jr.

H. W. Clark, Jr., Manager
Nuclear Radiation Department

This Document is UNCLASSIFIED

C. K. Mitchell

C. K. Mitchell
Classification Officer

This work was performed by EG&G/EM for the Environmental Protection Agency through an EAO Transfer of Funds to Contract Number DE-AC08-83NV10282 with the United States Department of Energy.

CONTENTS

ILLUSTRATIONS

ILLUSTRATIONS (Cont)

bismuth concentrations. This can only be determined by ground-based measurements and, to some extent, by photo interpretation based on historical information.

The Bi-214 extraction procedure requires that an estimate of the natural background radiation contribution be subtracted from a portion of the energy spectra that is dominated by the 1.76 MeV Bi-214 photopeak. The background contribution is estimated by comparing the ratio (k) of total counts in a window typified by background radiation to the total counts in the window dominated by Bi-214 observed in an area exhibiting only natural background radiation. A typical gamma spectrum indicating these windows is shown in Figure 1. The photopeak window A (1.58 to 1.93 MeV) accepts the 1.76 MeV gammas from Bi-214. The background window B (2.36 to 2.864 MeV) accepts the 2.61 MeV gammas from Tl-208. The combination of the background window B and the ratio k is used to remove counts due to higher energy gammas from naturally-occurring radionuclides from the Bi-214 window A. The equation for expressing the removal of background count rates from the Bi-214 window is as follows:

$$\text{Net Bi-214} = A - k(B)$$

The data presented in the Results section are reported in net counts per second. Table 2 provides conversion factors relating net Bi-214 photopeak count rates to source concentration values for a variety of source distributions.

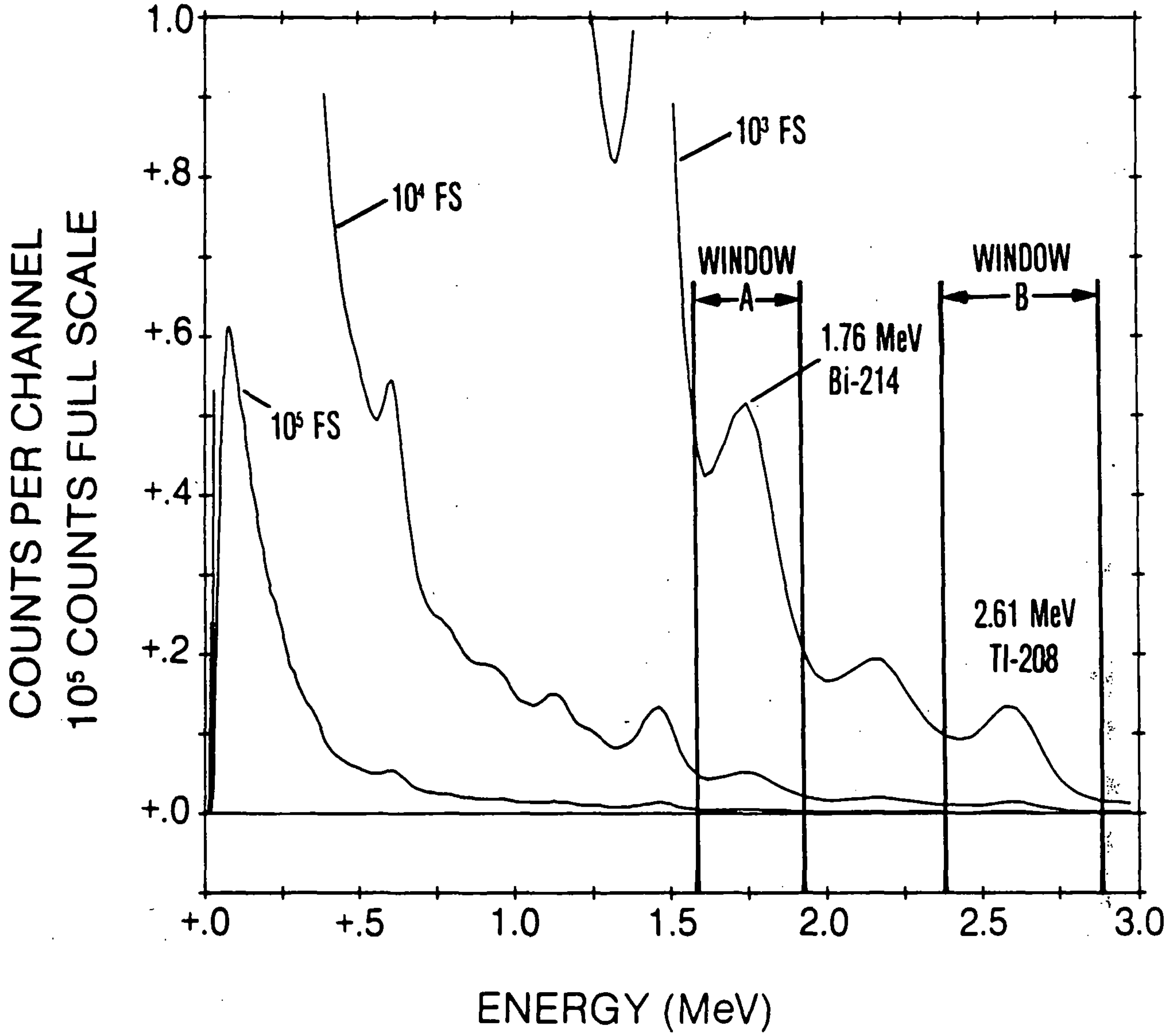


Figure 1 Typical Gamma Spectrum Indicating the Bismuth-214 Extraction Windows.

Table 2. Conversion Factors Relating Aerial Photopeak Count Rate Data to Bismuth-214[a] Concentration on the Ground for a Variety of Source Distribution Geometries

Conversion Factor[b]					
Point Source on Surface µCi/cps		Uniform Surface Distribution	Exponential Distribution		Uniform Volume Distribution
Directly Under Aircraft	At Lateral Distance of 45 m	µCi/m2 / cps	Relaxation Depth (cm)	µCi/m2 / cps	pCi/g[c] / cps
104	208	4.9(10-3)	0.1 1.0 10.0	5.0(10-3) 5.9(10-3) 1.3(10-2)	5.8(10-2)

[a]1.76 MeV photopeak.

[b]Conversion factors are given for the 20 12.7-cm x 5-cm NaI(Tl) detector array at an altitude of 46 meters (150 feet), assuming an air density of 1.0 g/l and a soil density of 1.5 g/cm^3 (10% soil moisture content). All results are computed for an isotropic detector angular response.

[c]1.82 µR/h/pCi/g for the entire radium-226 daughter series, assuming all members of the series are in equilibrium.

The conversion factors for Bi-214 activity also assume a uniformly distributed source covering an area which is large compared to the detector system field-of-view (approximately 350 meters in diameter for the 1.76 MeV gammas of Bi-214 at the survey altitude of 46 meters). For a finite source distribution which is small compared to the field-of-view of the detector system, it is necessary to modify or correct the data by utilizing the information in Table 3. As with the total terrestrial exposure rate values, the actual exposure rate or activity values contributed solely from Bi-214 could be significantly higher than those reported for a source localized in a small area.

Table 3. Finite Bismuth-214 Correction Factors Versus Area of Source

Source Diameter (meter)	Correction Factor
12	90
24	21
50	6
80	3
140	1.7
180	1.4
300	1.1
350	1.1
>350	1.0

As stated previously, the airborne system can "see," to some degree, anomalies that are off to the side of the aircraft in addition to those directly below. Table 4 gives the point source conversion factors for a Bi-214 source on the surface of the ground for various lateral displacements up to 45 meters (148 feet).

Table 4. Bismuth-214 Point Source Conversion Factors

Lateral Displacement (meters)	mCi Per Count Per Second[a]
0	0.104
9	0.108
18	0.120
27	0.140
36	0.170
45	0.208

[a]Assuming an aircraft velocity of 36 meters/second (70 knots) and an altitude of 46 meters (150 feet).

6. GROUND-BASED MEASUREMENTS

Exposure rates were measured at seven locations by the EPA during the survey period to verify the integrity of the aerial results. The locations for the ground-based measurements were chosen to be in areas which were assumed to exhibit only a natural background radiation level and away from any obvious anomalies. A Reuter-Stokes pressurized ion chamber (PIC) Model RSS-111 was used for each series of exposure measurements at a 1-meter height.

7. AERIAL SURVEY RESULTS

The results of the aerial radiological surveys conducted over each of the three areas (Pocatello, Fort Hall, and Soda Springs) are presented as contours of terrestrial gamma exposure rates and Bi-214 net count rates superimposed on aerial photographs of the respective sites.

The gamma exposure rate contours report the total external exposure rate due to uniformly distributed terrestrial sources in μR/h extrapolated to 1 meter above ground level and include a cosmic ray exposure rate of 5.4 μR/h for Pocatello and Fort Hall and 6.4 μR/h for Soda Springs. The cosmic ray exposure rate contributions vary due to the difference in the average elevation at the respective sites. In addition, the exposure rates reported over highly localized sources of radiation may be underestimated due to the large-area averaging by the aerial detection system.

7.1 Pocatello Survey Results and Discussion

For better resolution in presenting the data, the Pocatello survey area has been divided into four areas of interest. The Pocatello survey boundary and the areas of interest are illustrated in Figure 2. Table 5 provides a brief location description of each area.

Table 5. Areas of Interest Descriptions	
AREA	DESCRIPTION
Area 1	Northwest portion of the survey area that includes the FMC and Simplot sites and the municipal airport.
Area 2	Northeast portion of the survey area that includes the town of Chubbuck, the I-15 and I-86 interchange, some industrial complexes and Pineridge Mall.
Area 3	Center portion of the survey area that includes primarily the downtown area.
Area 4	Southern portion of the survey area that includes the southern portion of downtown and the Portneuf area.

The total terrestrial gamma exposure rate contour maps of the four areas are presented in Figures 3 (Area 1), 4 (Area 2), 5 (Area 3) and 6 (Area 4). As observed in Figures 3 through 6, the background exposure rates generally range from 11 to 17 μR/h (C-D levels) for all four areas of interest. As indicated in the figures, there are several areas where the total terrestrial exposure rate is considerably higher than the normal background range. The areas of higher than background exposure rate can be attributed to excess Bi-214.

The excess Bi-214 net count rate contour maps of the four areas of interest are shown in Figures 7, 8, 9 and 10. As stated in Section 5, the 1.76 MeV photopeak was utilized in mapping the areas of excess bismuth. The A-level contours represent the normal range of background levels of Bi-214; levels B and above represent areas of excess bismuth. In Area 1 (Figure 7), the FMC and Simplot plant sites clearly exhibit areas of higher than normal concentrations of Bi-214. In addition, the airport, several roads and highways, and the railroad tracks exhibit excess levels of bismuth. As indicated in Figures 8, 9 and 10, there are extensive areas with higher than normal concentrations of Bi-214 throughout the Pocatello valley.

7.2 Fort Hall Survey Results and Discussion

The total terrestrial gamma exposure rate contour map for the Fort Hall survey area is shown in Figure 11. As in the Pocatello survey area, the observed background exposure rate values range from 11 to 17 μR/h (C-D levels) for the majority of the area. There are a few areas where the exposure rates range to just over twice background.

The excess Bi-214 net count rate contour map is presented in Figure 12. The areas exhibiting excess bismuth (B level and higher) are fairly localized and associated primarily with paved areas.

7.3 Soda Springs Survey Results and Discussion

The total terrestrial gamma exposure rate contour map for the Soda Springs survey area is shown in Figure 13. The observed background exposure rates for the area range from 12 to 17 μR/h (C-D levels). As in the Pocatello survey, there are several areas where the total terrestrial exposure rate is considerably higher than background. These areas of higher exposure rates can also be attributed to excess bismuth concentrations.

Figure 14 represents the excess Bi-214 net count rates. The primary areas exhibiting excess concentrations of bismuth are the Monsanto elemental phosphorus plant, the Kerr-McGee vanadium plant, the primary highways that run through town and some secondary roads, and a few localized areas throughout the town.

7.4 Comparison of Aerial Survey Results and Ground-Based Measurements

Pressurized ion chamber measurements were collected at seven locations within the three survey areas. A total of three measurements each were collected within the Pocatello and Soda Springs survey areas and one in the Fort Hall survey area. The site locations (Numbers 1 through 7) are labeled on the appropriate figures (Figures 3, 4, 6, 11, and 13).

As indicated in Table 6, which presents a comparison of the ground-based and aerial platform measurements, the PIC measurements generally agree with the aerial measurement interval at each site.

Table 6. Comparison of Aerial and Ground-Based Measurements			
Sample Location	Corresponding Figure	Exposure Rate (μR/h at 1 Meter Above Ground Level)	
		Ion Chamber[a]	Inferred Aerial Data[b]
1	Figure 3	14.1	14.5- 17
2	Figure 4	13.6	11 - 14.5
3	Figure 6	12.3	11 - 14.5
4	Figure 11	13.1	11 - 14.5
5	Figure 13	16.2	17 - 22
6	Figure 13	13.8	15 - 17
7	Figure 13	15.2	17 - 22

[a]Reuter-Stokes Model RSS-111, Serial No. 140574.

[b]Includes a cosmic contribution.

There are several contributors to differences among the measurement methods:

1. The aerial data were not taken at exactly the same places or times as the ground data.

2. Each 1-second data point obtained with the airborne system covers an area several thousand times as large as the PIC measurement made at 1 meter.

3. The airborne detection systems "blur" the apparent edges of small anomalies; i.e., the airborne system can "see," to some degree, anomalies that are off to the side of the aircraft in addition to those directly below. Therefore, adjacent roads and/or paved areas where phosphate slag has been used as a base material will produce a slightly higher than normal result in an apparently undisturbed background area.

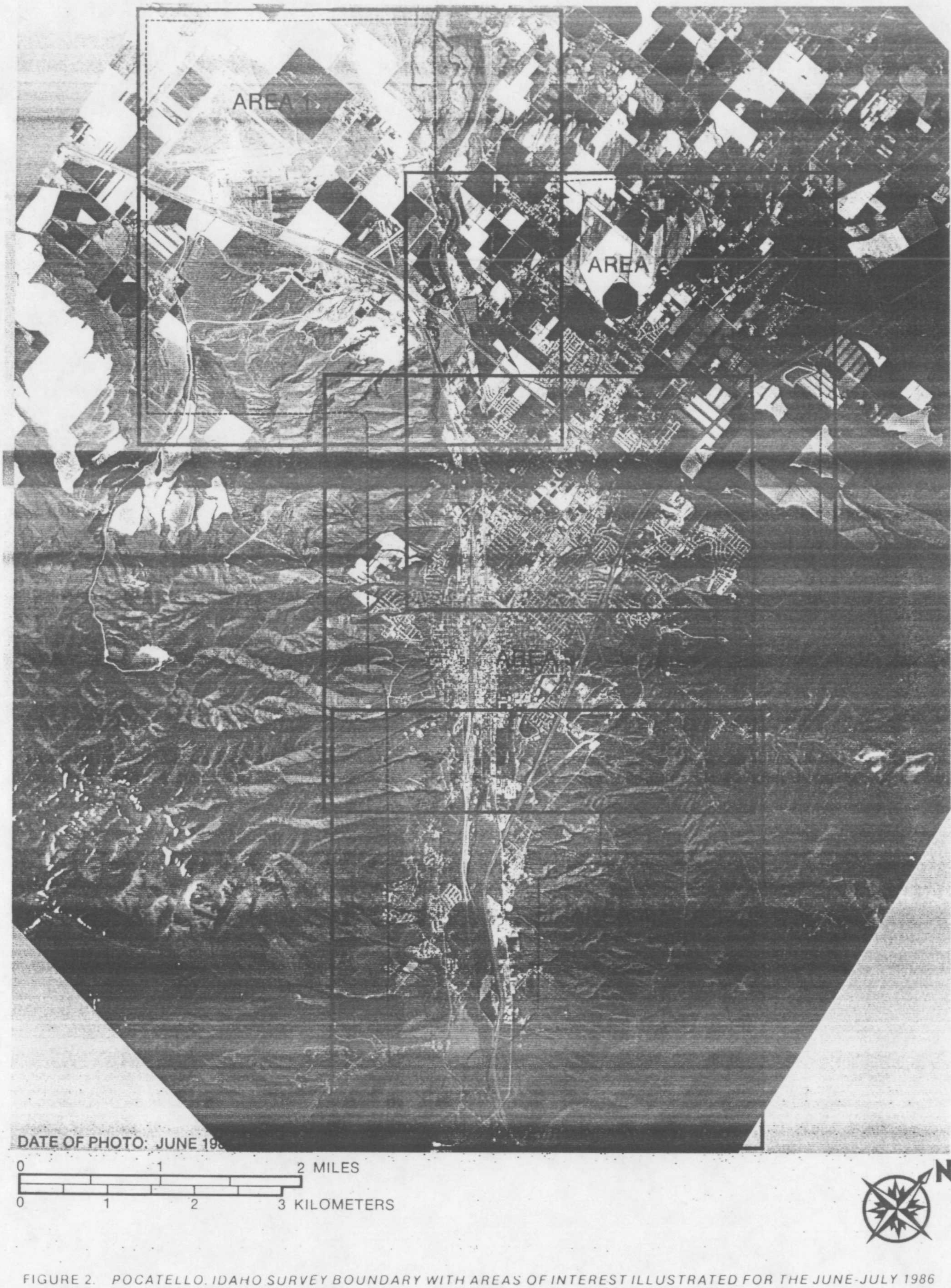
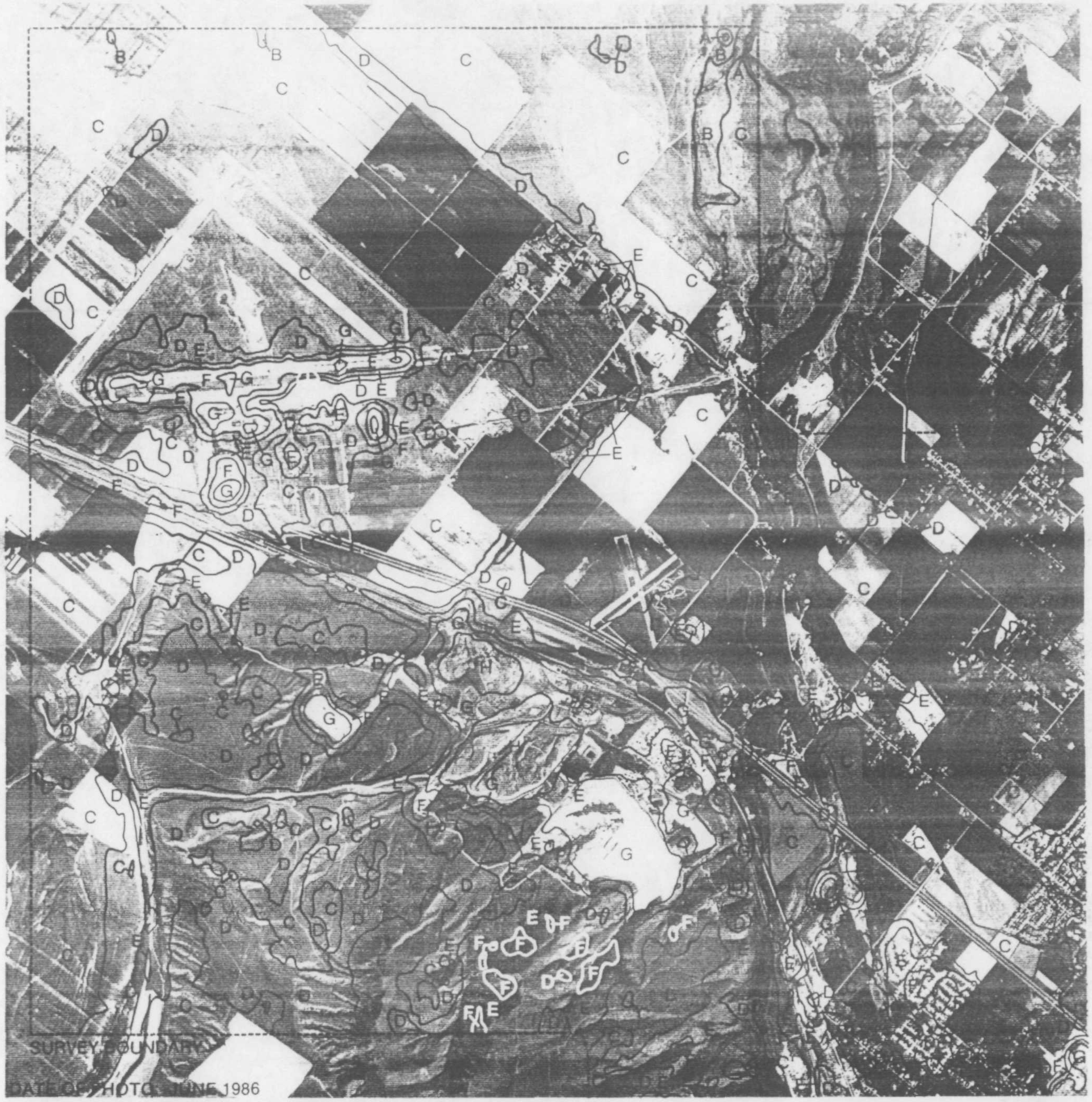
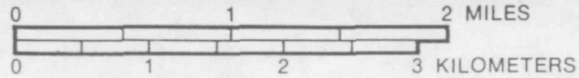


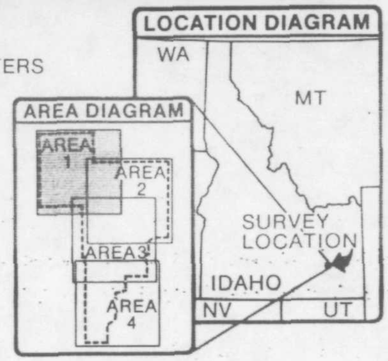
FIGURE 2. POCATELLO, IDAHO SURVEY BOUNDARY WITH AREAS OF INTEREST ILLUSTRATED FOR THE JUNE-JULY 1986 AERIAL RADIOLOGICAL SURVEY



CONVERSION SCALE	
LETTER LABEL	TERRESTRIAL GAMMA EXPOSURE RATE AT 1 METER* (μR/h)
A	< 9
B	9 - 11
C	11 - 14.5
D	14.5 - 17
E	17 - 22
F	22 - 30
G	30 - 50
H	50 - 100

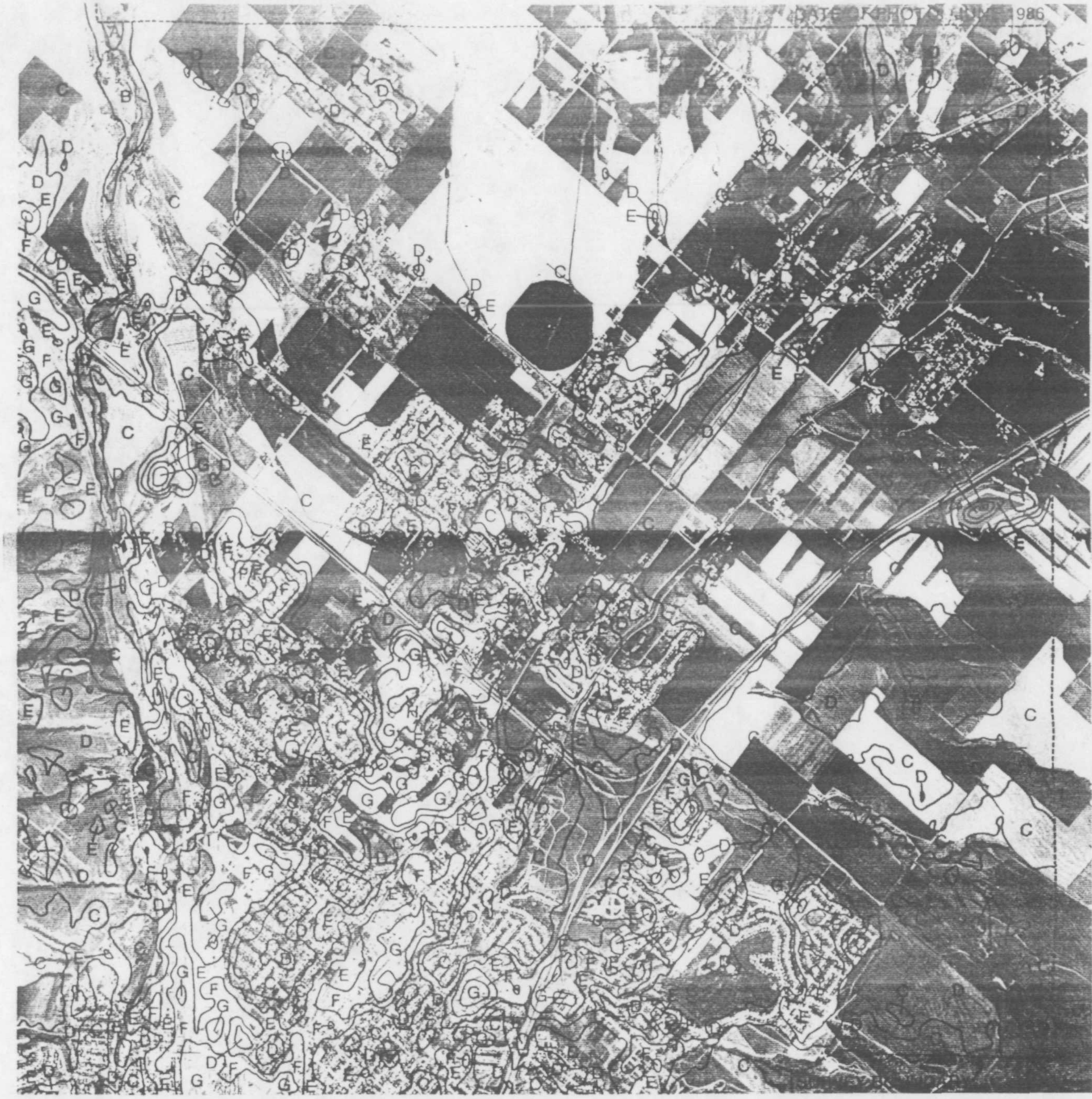


GROUND MEASUREMENT LOCATION



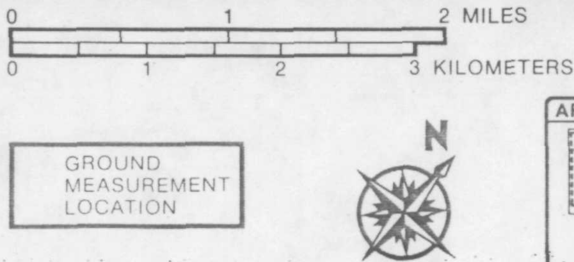
* Values are inferred from aerial data collected at an altitude of 46 meters AGL. Also includes an estimated cosmic ray contribution of 5.4 μR/h.

FIGURE 3. *TERRESTRIAL GAMMA RADIATION EXPOSURE RATE CONTOURS DERIVED FROM AERIAL DATA OBTAINED IN JUNE-JULY 1986 OVER AREA 1 OF POCATELLO, IDAHO AND SURROUNDING AREA*



LETTER LABEL	TERRESTRIAL GAMMA EXPOSURE RATE AT 1 METER* (μR/h)
A	< 9
B	9 - 11
C	11 - 14.5
D	14.5 - 17
E	17 - 22
F	22 - 30
G	30 - 50
H	50 - 100

CONVERSION SCALE



GROUND MEASUREMENT LOCATION

* Values are inferred from aerial data collected at an altitude of 46 meters AGL. Also includes an estimated cosmic ray contribution of 5.4 μR/h.

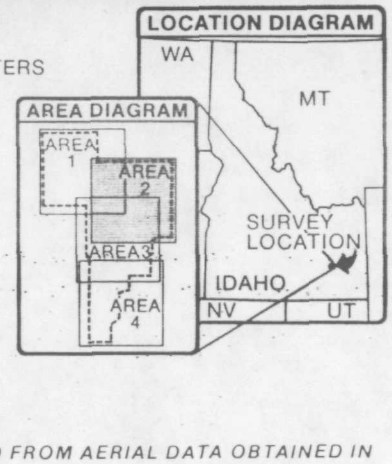
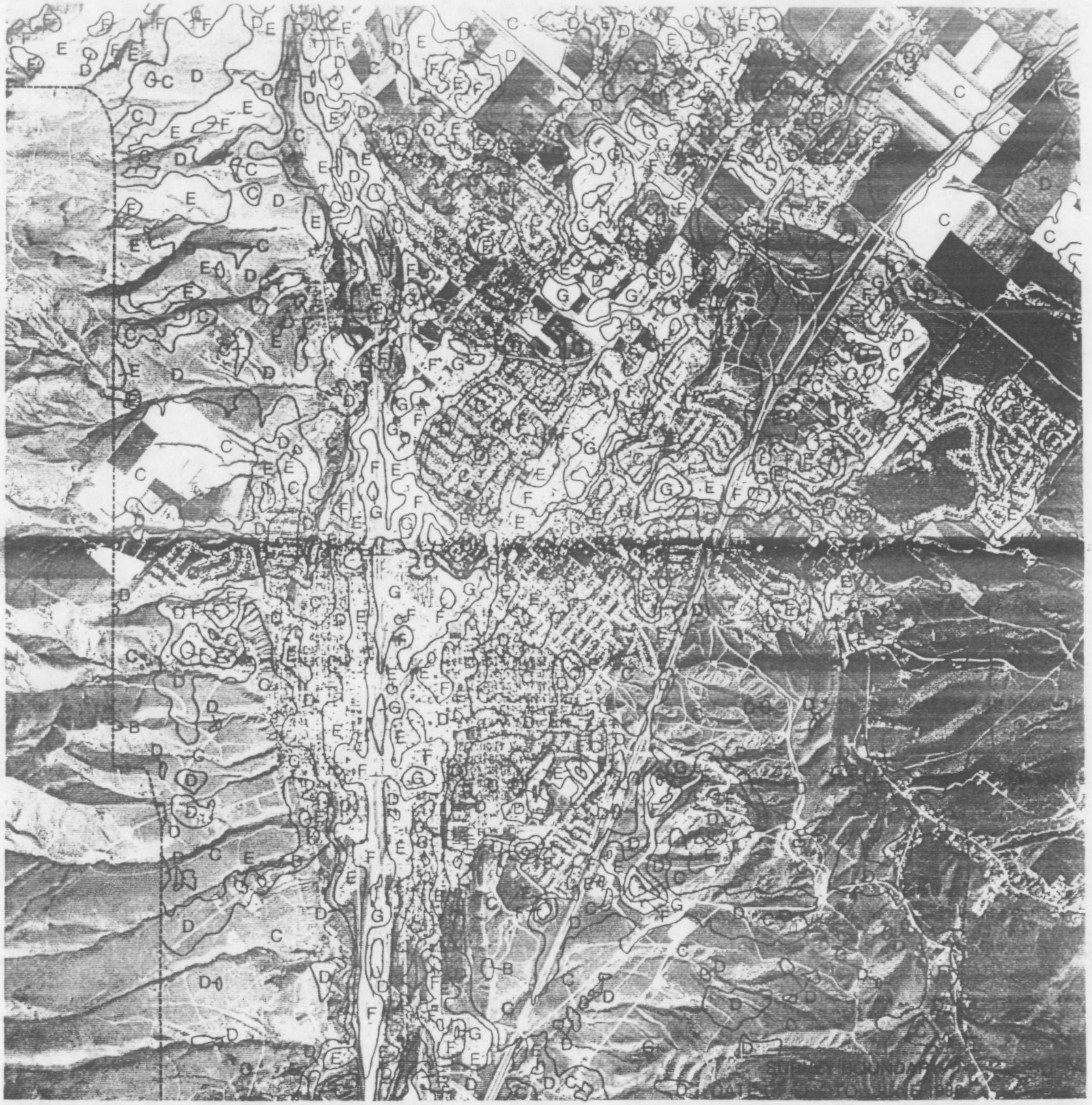
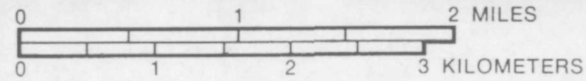


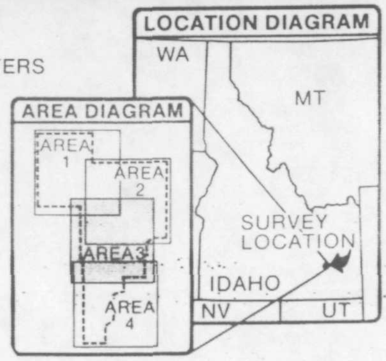
FIGURE 4. *TERRESTRIAL GAMMA RADIATION EXPOSURE RATE CONTOURS DERIVED FROM AERIAL DATA OBTAINED IN JUNE-JULY 1986 OVER AREA 2 OF POCATELLO, IDAHO AND SURROUNDING AREA*



LETTER LABEL	TERRESTRIAL GAMMA EXPOSURE RATE AT 1 METER* (μR/h)
A	< 9
B	9 - 11
C	11 - 14.5
D	14.5 - 17
E	17 - 22
F	22 - 30
G	30 - 50
H	50 - 100

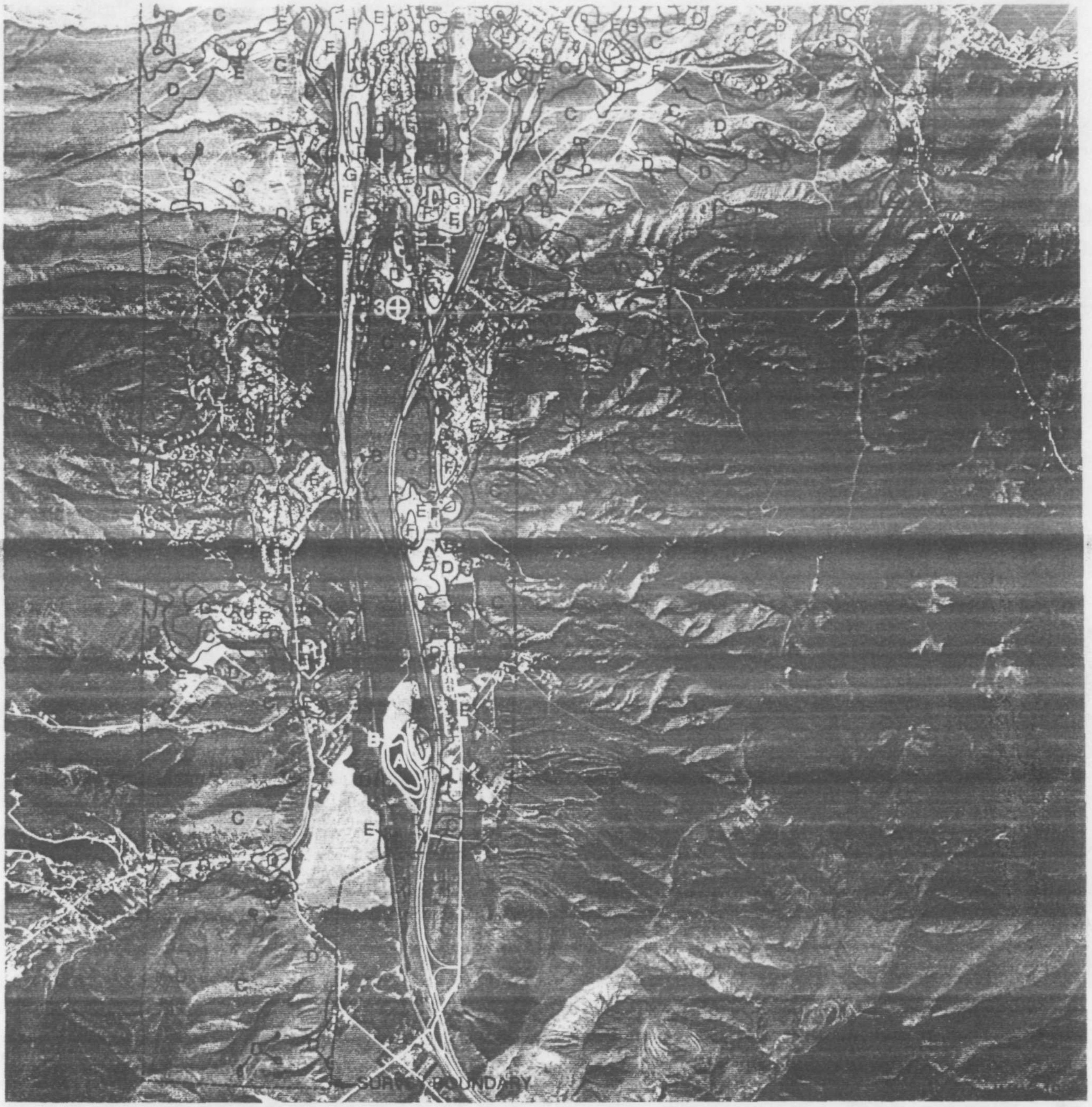
Table title: CONVERSION SCALE





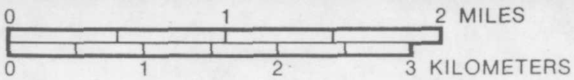
* Values are inferred from aerial data collected at an altitude of 46 meters AGL. Also includes an estimated cosmic ray contribution of 5.4 μR/h.

FIGURE 5. *TERRESTRIAL GAMMA RADIATION EXPOSURE RATE CONTOURS DERIVED FROM AERIAL DATA OBTAINED IN JUNE-JULY 1986 OVER AREA 3 OF POCATELLO, IDAHO AND SURROUNDING AREA*



CONVERSION SCALE

LETTER LABEL	TERRESTRIAL GAMMA EXPOSURE RATE AT 1 METER* (μR/h)
A	< 9
B	9 - 11
C	11 - 14.5
D	14.5 - 17
E	17 - 22
F	22 - 30
G	30 - 50



GROUND MEASUREMENT LOCATION

* Values are inferred from aerial data collected at an altitude of 46 meters AGL. Also includes an estimated cosmic ray contribution of 5.4 μR/h.

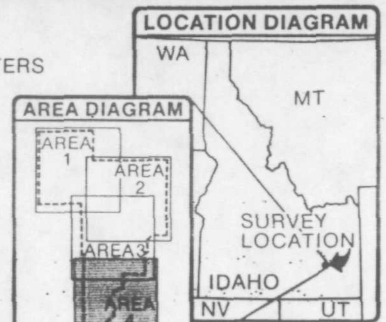
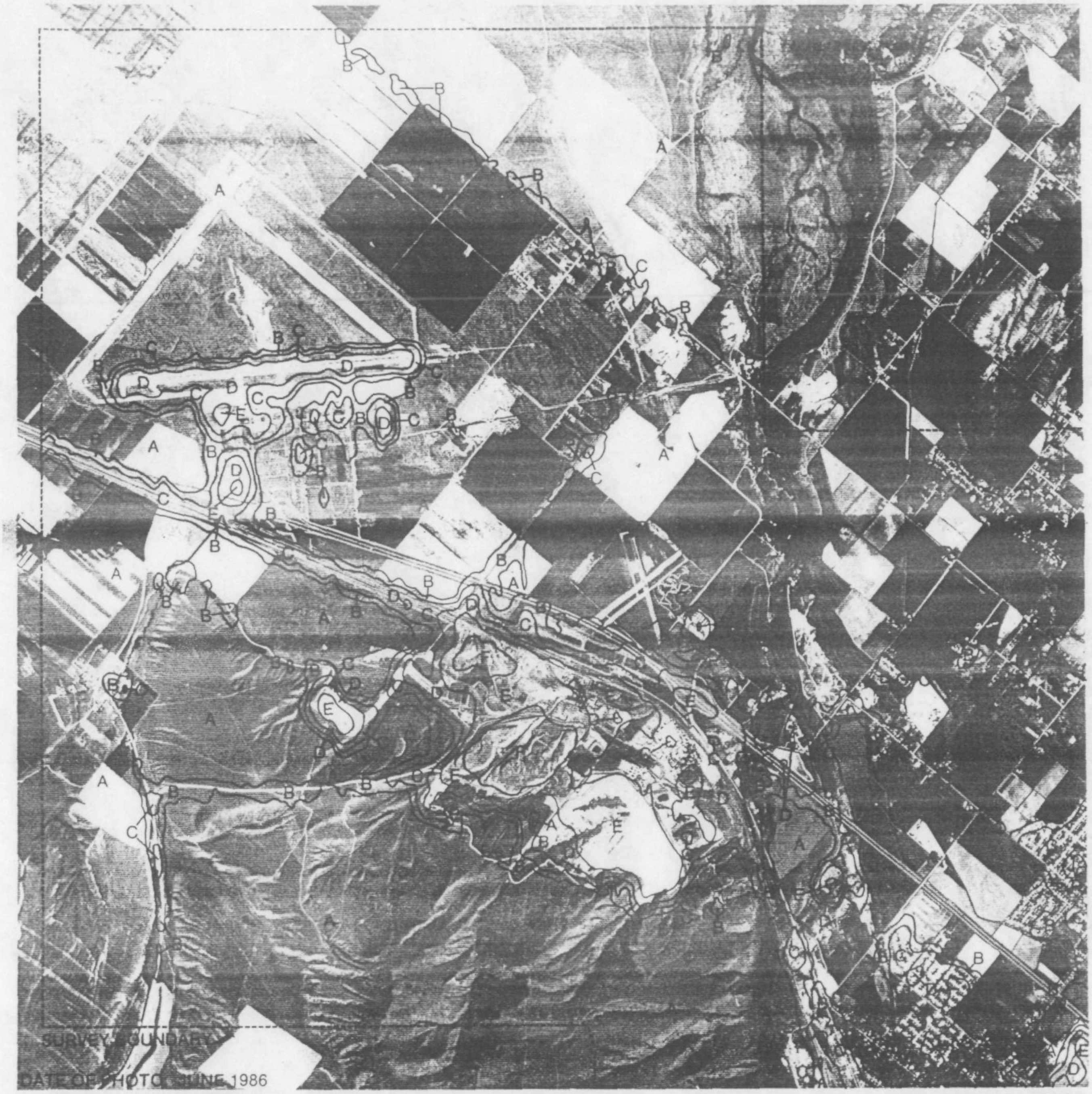
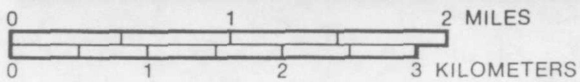


FIGURE 6. *TERRESTRIAL GAMMA RADIATION EXPOSURE RATE CONTOURS DERIVED FROM AERIAL DATA OBTAINED IN JUNE-JULY 1986 OVER AREA 4 OF POCATELLO, IDAHO AND SURROUNDING AREA*



CONVERSION SCALE	
LETTER LABEL	NET COUNTS PER SECOND*
A	< 28
B	28 - 60
C	60 - 130
D	130 - 280
E	280 - 600
F	600 - 1300

*Net gross counts above background in the window 1.58 to 1.93 MeV.



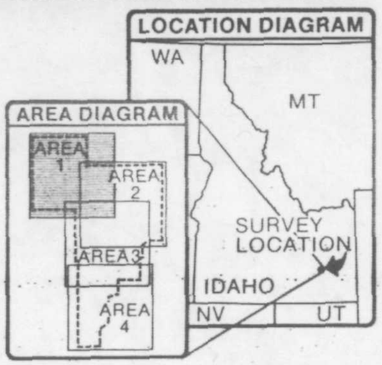
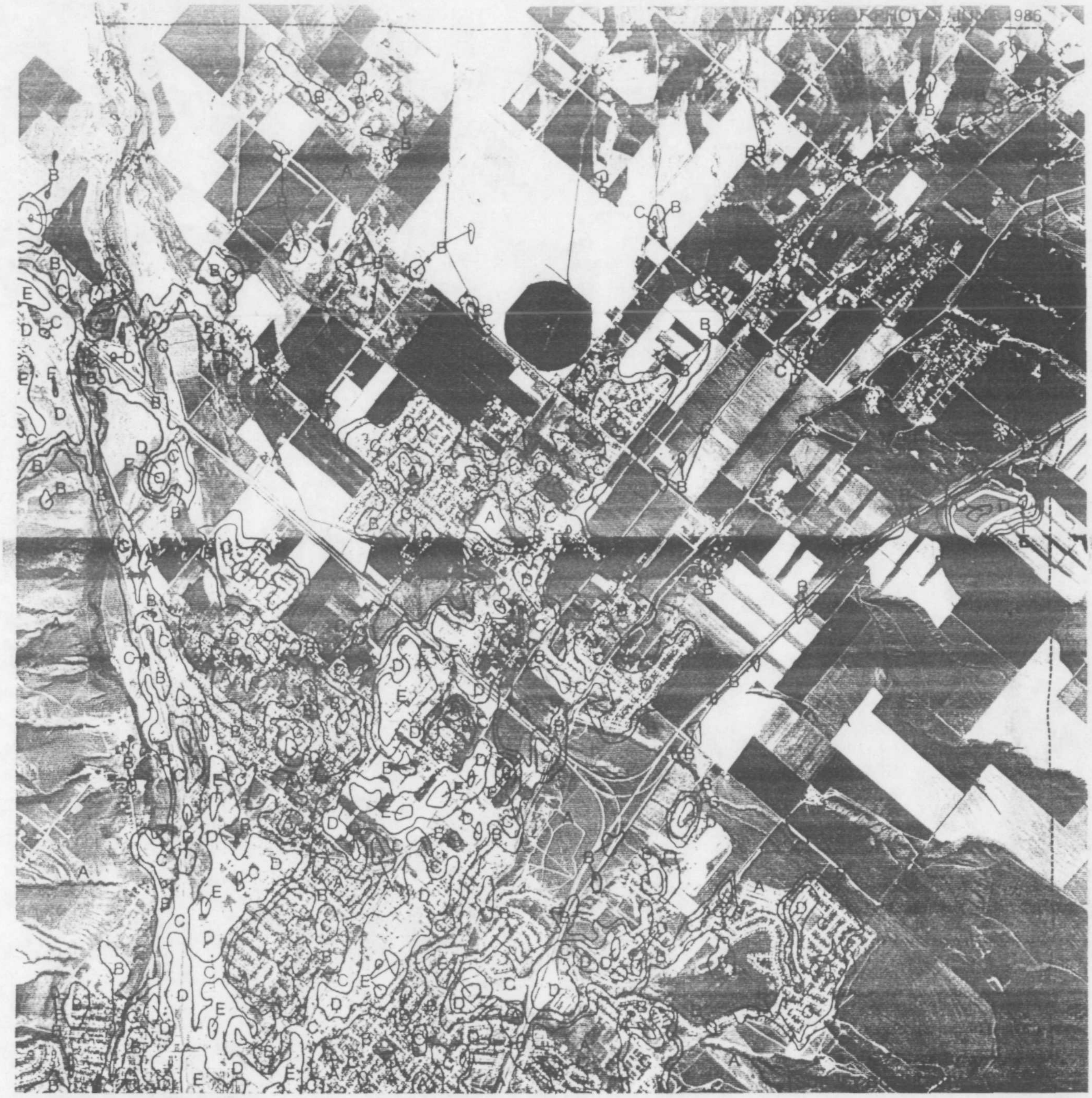


FIGURE 7. *BISMUTH-214 NET COUNT RATE CONTOURS DERIVED FROM AERIAL DATA OBTAINED IN JUNE-JULY 1986 OVER AREA 1 OF POCATELLO, IDAHO AND SURROUNDING AREA*



CONVERSION SCALE	
LETTER LABEL	NET COUNTS PER SECOND*
A	< 28
B	28 - 60
C	60 - 130
D	130 - 280
E	280 - 600

*Net gross counts above background in the window 1.58 to 1.93 MeV.

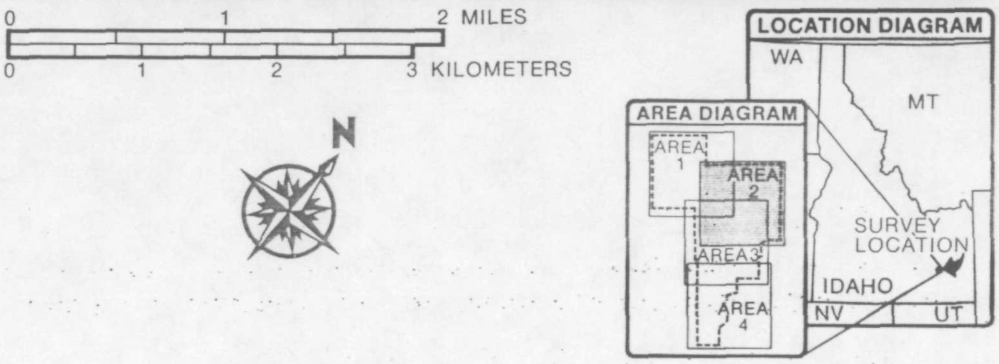
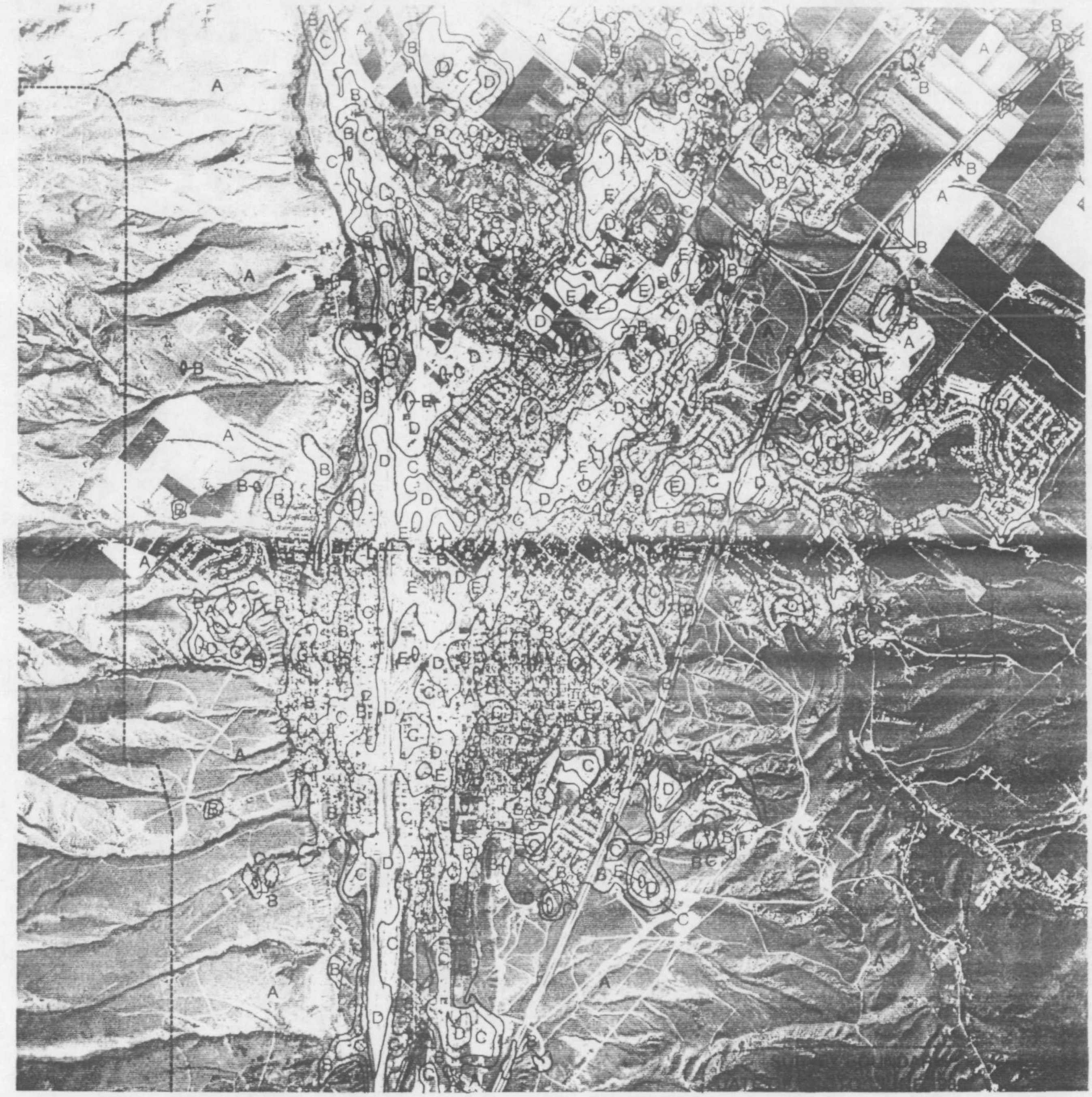


FIGURE 8. *BISMUTH-214 NET COUNT RATE CONTOURS DERIVED FROM AERIAL DATA OBTAINED IN JUNE-JULY 1986 OVER AREA 2 OF POCATELLO, IDAHO AND SURROUNDING AREA*



CONVERSION SCALE	
LETTER LABEL	NET COUNTS PER SECOND*
A	< 28
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C	60 - 130
D	130 - 280
E	280 - 600

*Net gross counts above background in the window 1.58 to 1.93 MeV.

0 1 2 MILES

0 1 2 3 KILOMETERS

N

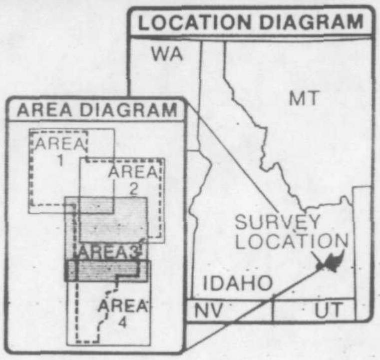


FIGURE 9. *BISMUTH-214 NET COUNT RATE CONTOURS DERIVED FROM AERIAL DATA OBTAINED IN JUNE-JULY 1986 OVER AREA 3 OF POCATELLO, IDAHO AND SURROUNDING AREA*

CONVERSION SCALE	
LETTER LABEL	NET COUNTS PER SECOND*
A	< 28
B	28 - 60
C	60 - 130
D	130 - 280
E	280 - 600

*Net gross counts above background in the window 1.58 to 1.93 MeV.

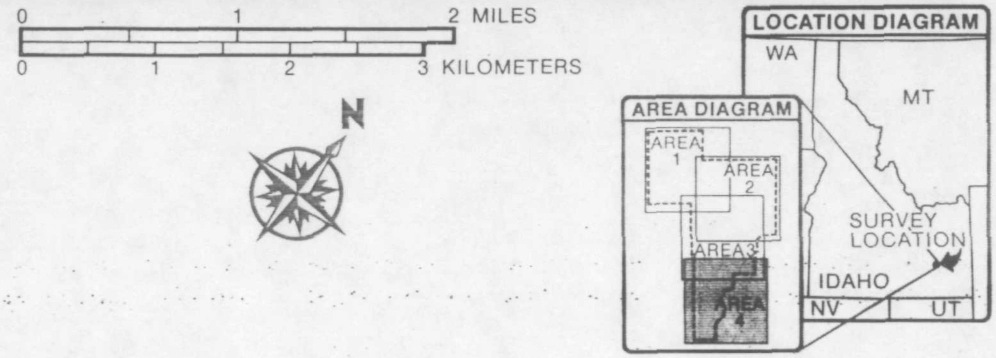
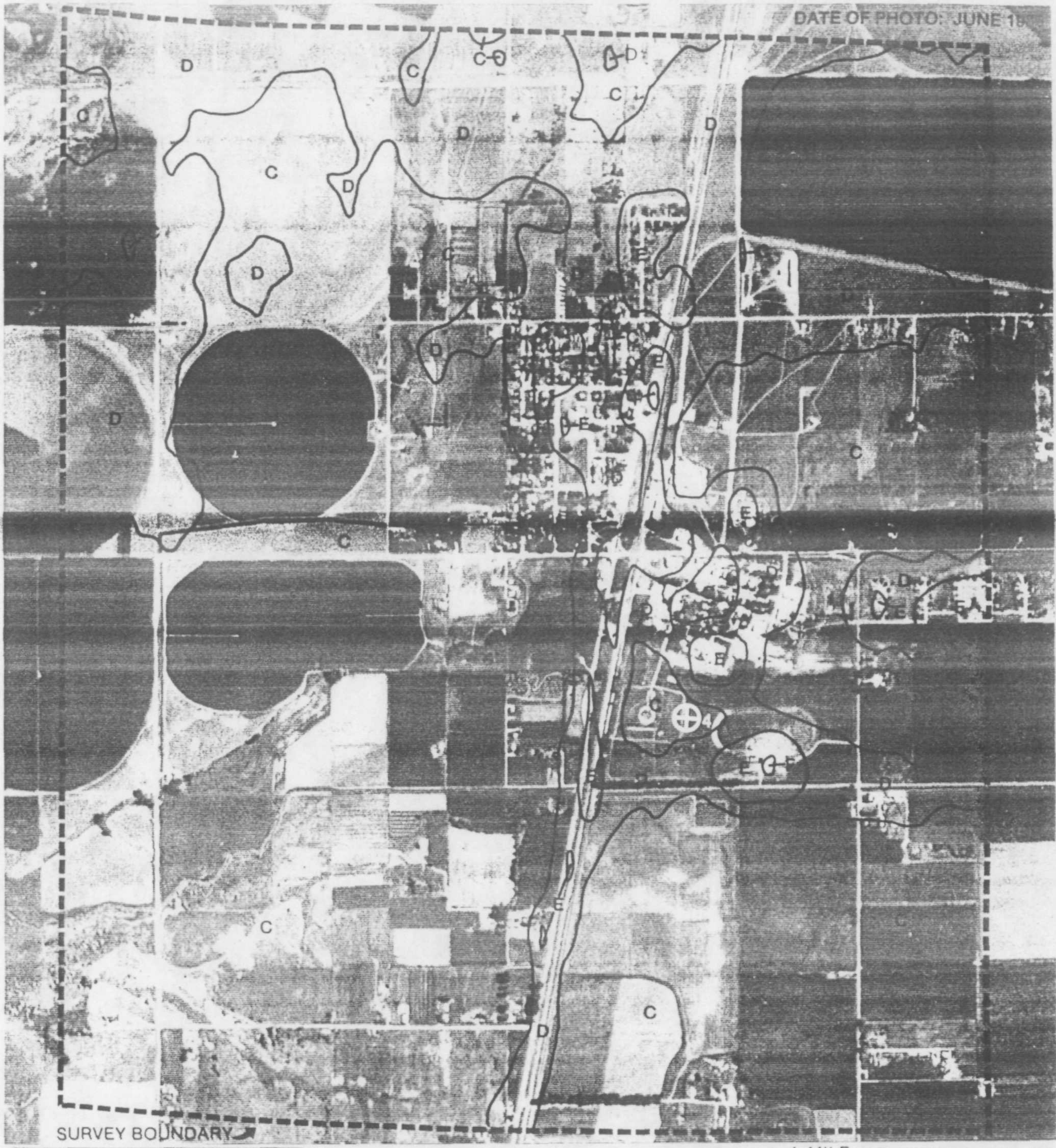


FIGURE 10. *BISMUTH-214 NET COUNT RATE CONTOURS DERIVED FROM AERIAL DATA OBTAINED IN JUNE-JULY 1986 OVER AREA 4 OF POCATELLO, IDAHO AND SURROUNDING AREA*



CONVERSION SCALE	
LETTER LABEL	TERRESTRIAL GAMMA EXPOSURE RATE AT 1 METER* (μR/h)
A	< 9
B	9 - 11
C	11 - 14.5
D	14.5 - 17
E	17 - 22
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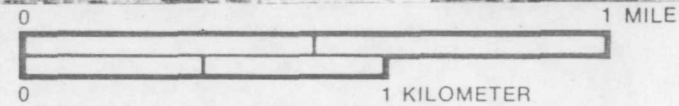
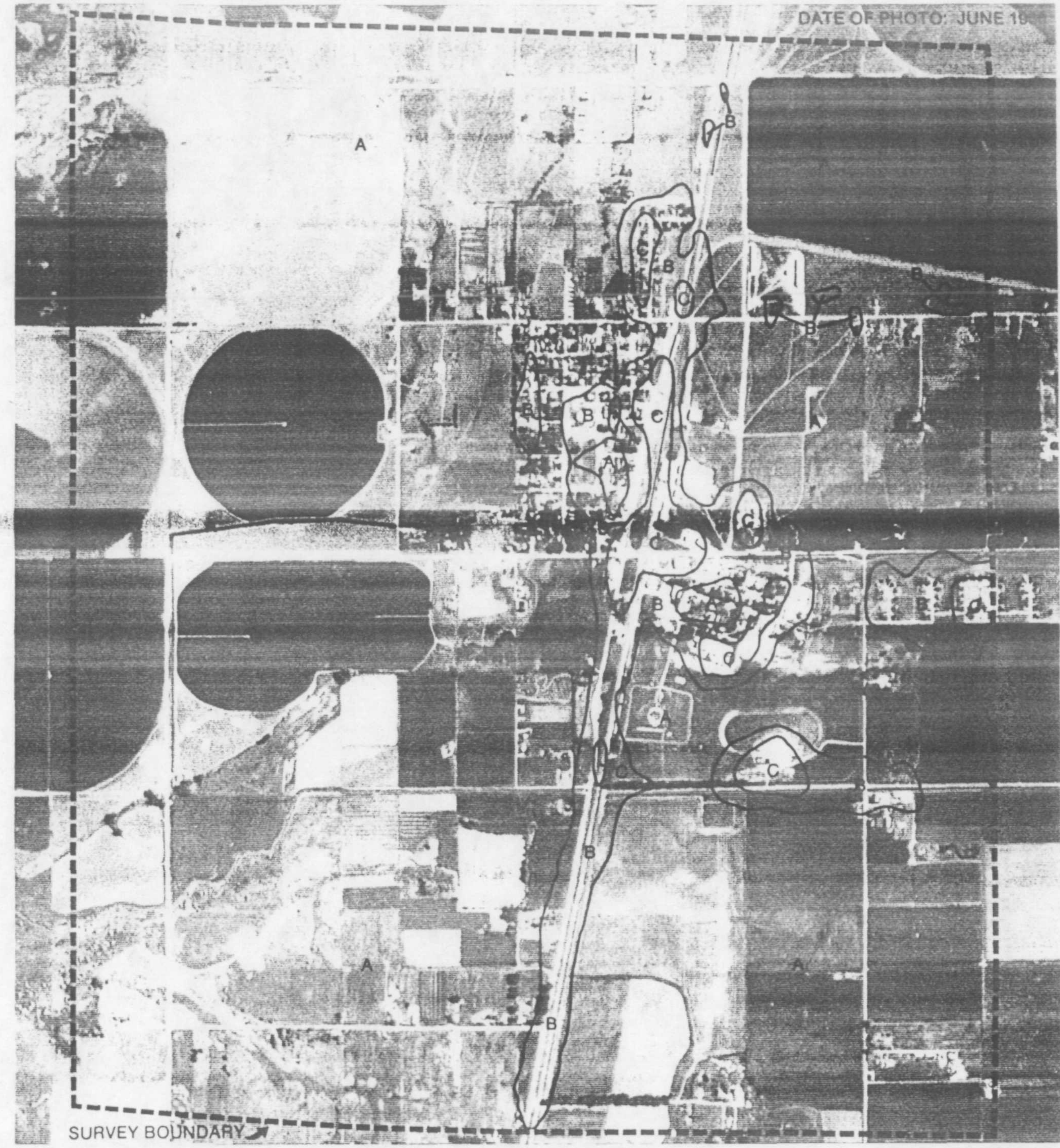


GROUND MEASUREMENT LOCATION

*Values are inferred from aerial data collected at an altitude of 46 meters AGL. Also includes an estimated cosmic ray contribution of 5.4 μR/h.

FIGURE 11. *TERRESTRIAL GAMMA RADIATION EXPOSURE RATE CONTOURS DERIVED FROM AERIAL DATA OBTAINED IN JULY 1986 OVER FORT HALL, IDAHO AND SURROUNDING AREA*



CONVERSION SCALE	
LETTER LABEL	NET COUNTS PER SECOND*
A	< 28
B	28 - 60
C	60 - 130

*Net gross counts above background in the window 1.58 to 1.93 MeV.

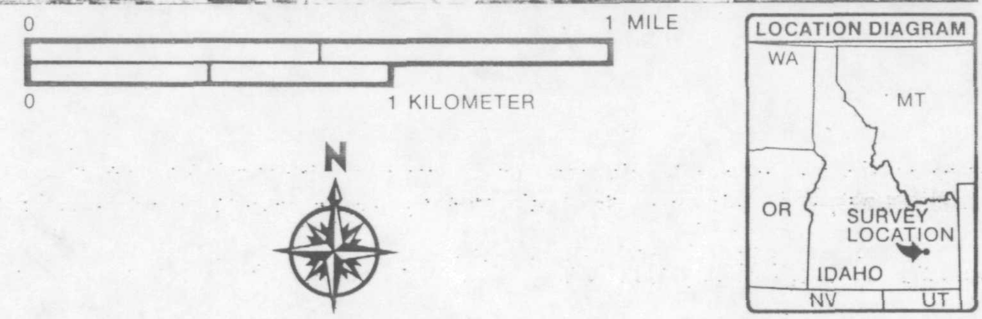
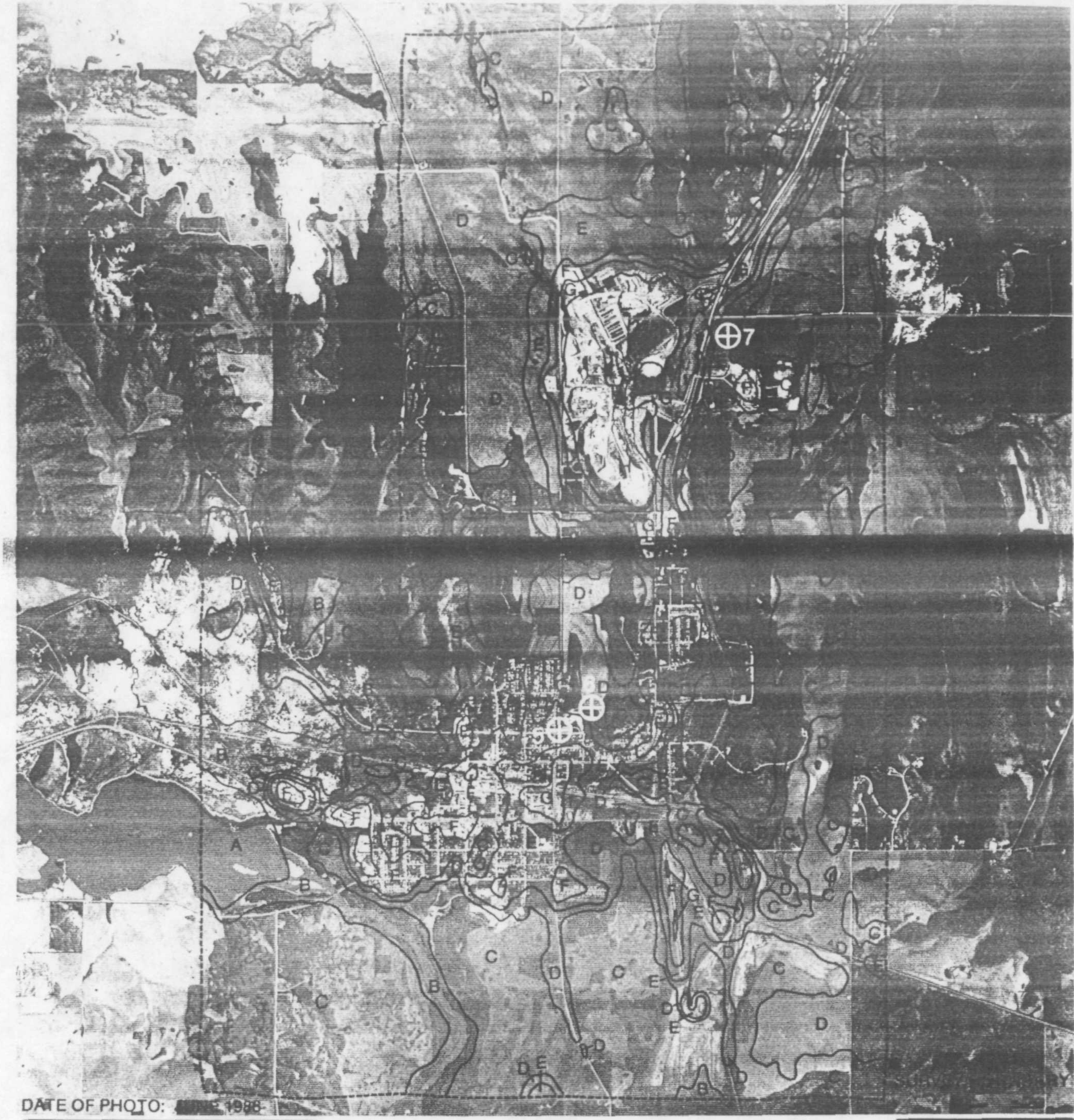
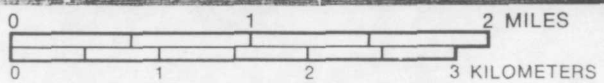


FIGURE 12. *BISMUTH-214 NET COUNT RATE CONTOURS DERIVED FROM AERIAL DATA OBTAINED IN JULY 1986 OVER FORT HALL, IDAHO AND SURROUNDING AREA*



CONVERSION SCALE

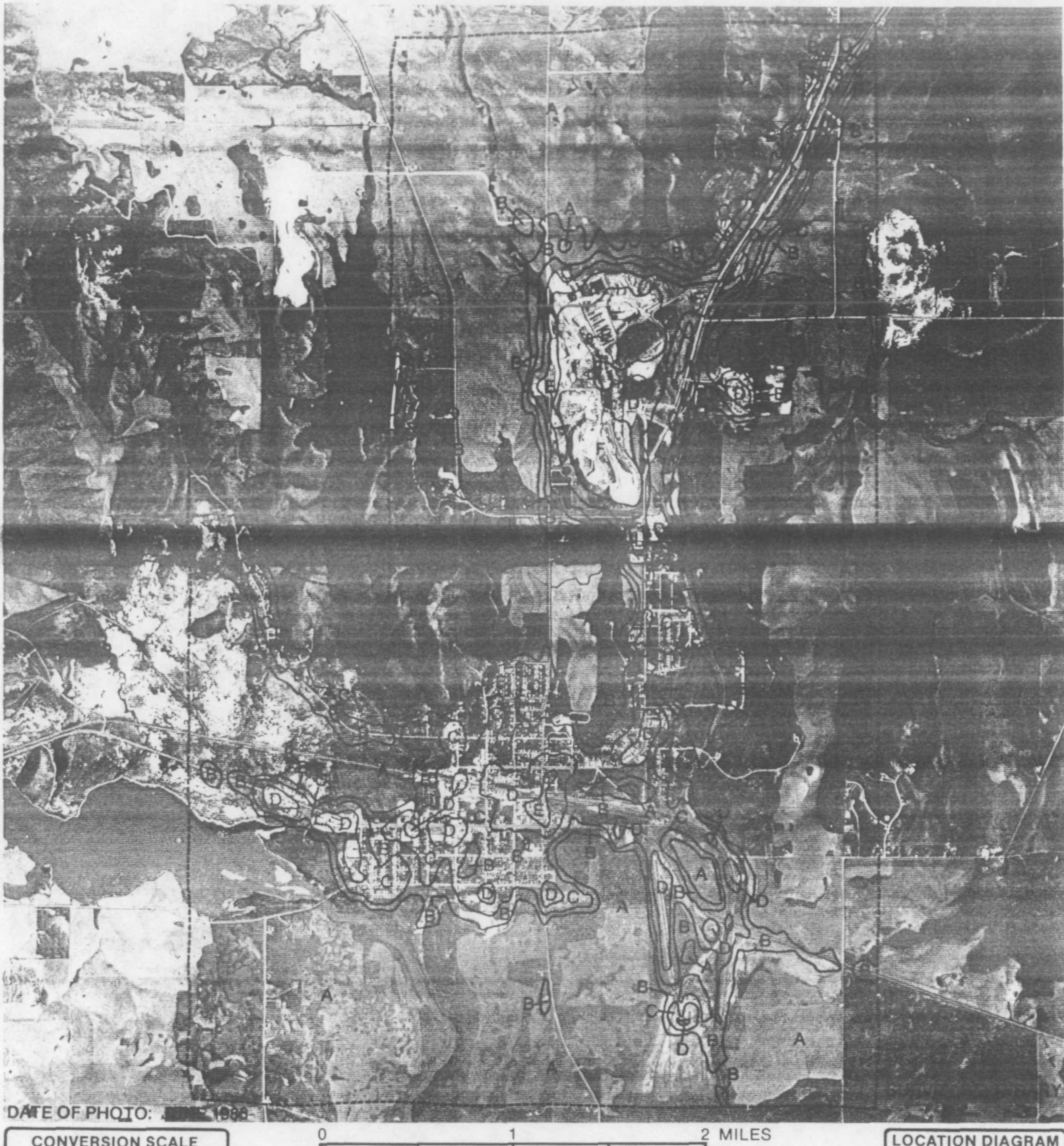
LETTER LABEL	TERRESTRIAL GAMMA EXPOSURE RATE AT 1 METER* (μR/h)
A	< 9
B	9 - 12
C	12 - 15
D	15 - 17
E	17 - 22
F	22 - 30
G	30 - 50
H	50 - 100



⊕ GROUND MEASUREMENT LOCATION

* Values are inferred from aerial data collected at an altitude of 46 meters AGL. Also includes an estimated cosmic ray contribution of 6.4 μR/h.

FIGURE 13. *TERRESTRIAL GAMMA RADIATION EXPOSURE RATE CONTOURS DERIVED FROM AERIAL DATA OBTAINED IN JULY 1986 OVER SODA SPRINGS, IDAHO AND SURROUNDING AREA*



CONVERSION SCALE	
LETTER LABEL	NET COUNTS PER SECOND*
A	< 28
B	28 - 60
C	60 - 130
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E	280 - 600
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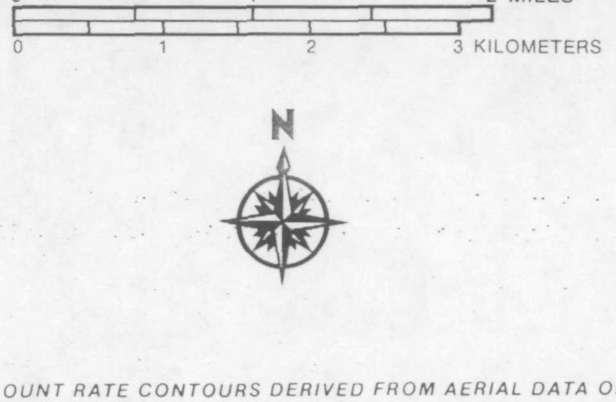
*Net gross counts above background in the window 1.58 to 1.93 MeV.



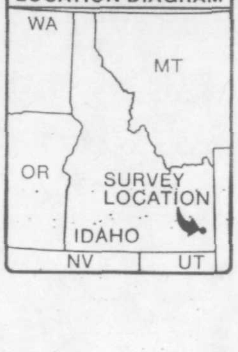


FIGURE 14. *BISMUTH-214 NET COUNT RATE CONTOURS DERIVED FROM AERIAL DATA OBTAINED IN JULY 1986 OVER SODA SPRINGS, IDAHO AND SURROUNDING AREA*

REFERENCES

1. Klement, A. W.; Miller, C. R.; Min, R. P.; Shleren, B. August 1972. Estimate of Ionizing Radiation Doses in the United States 1960-2000. U. S. EPA Report ORP/CD72-1. Washington, D. C.: Environmental Protection Agency.

2. Jobst, J. E. 1979. "The Aerial Measuring System Program." Nuclear Safety, March/April 1979, 20:136-147.

3. Clark, H. W. 1981. An Aerial Radiological Survey of the Federal-American Partners, Pathfinder, and Union Carbide Mill Sites and Surrounding Area, Gas Hills Mining District, Wyoming. Report No. NRC-8206. Las Vegas, NV: EG&G/EM.

4. Boyns, P. K. 1976. The Aerial Radiological Measuring System (ARMS): Systems, Procedures and Sensitivities. Report No. EGG-1183-1691. Las Vegas, NV: EG&G/EM.

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An Aerial Radiological Survey of
Pocatello and Soda Springs, Idaho
and Surrounding Area
EPA-8613
Date of Survey: June-July 1986
Date of Report: February 1987

Attachment O-2
FMC Gamma Radiation Survey

003400

FMC Corporation

Phosphorus Chemicals Division
Box 4111
Pocatello, Idaho 83205
(208) 236-8200
FAX (208) 236-8396

FMC

June 23, 1995

Mr. Bill Adams
U.S. EPA - Region 10
CERCLA Section, HW-113
1200 Sixth Avenue
Seattle, WA 98101

Re: Radiation Exposure Survey for FMC
Eastern Michaud Flats CERCLA Project

Dear Mr. Adams:

I have attached a report entitled "Gamma Radiation Survey, FMC-Pocatello, Idaho" conducted by J. L. Alvarez of IT Corporation. This report supplies site-specific information pertaining to gamma radiation exposures and the shielding factors afforded FMC workers by mobile equipment cabs.

As you know, the PRPs objected to the use of EPA's 1986 aerial gamma survey to characterize potential worker exposures to gamma radiation and resultant risk. FMC and our consultants feel that the IT Survey data are more appropriate for the Risk Assessment. The joint PRP letter commenting on EPA's draft risk assessment (dated June 20) indicated that FMC would be supplying the attached site-specific gamma radiation survey (Comment #7) to EPA.

Sincerely,

Jim Sieverson

J. P. Sieverson
FMC CERCLA Site Manager

Gamma Radiation Survey
FMC - Pocatello, Idaho

J. L. Alvarez
IT Corporation

Introduction

The FMC Plant in Pocatello, Idaho produces elemental phosphorus from phosphate shale. The shale and resultant slag contain naturally-occurring ^{238}U and progeny in concentrations higher than local background soil. Consequently both shale and slag emit more gamma radiation than local soil, thus exposing the workers to higher levels of ionizing radiation than the local background. The levels of radiation generally measured within the plant boundary and at specific locations directly above the slag were found not to be sufficient to require a radiation protection program under 29 CFR 1910.96. Nevertheless, FMC performs radiation measurements on an annual basis to ensure that the radiation environment has not changed sufficiently to require re-evaluation.

Because EPA raised the possibility of excess worker risk under provisions of CERCLA, FMC had a more extensive survey performed that would allow evaluation of risk, rather than the need for a radiation protection program. Key to that risk evaluation is the radiation shielding provided by equipment cabs and buildings. This survey presents gamma radiation measurements and calculated shielding factors for equipment cabs and structures around the FMC Plant.

Equipment and Methods

Worker activities include unloading and storage of phosphate shale; preparation of shale; furnace operations; handling of furnace products and byproducts, including slag; and general maintenance operations. Worker activities are usually conducted from inside the cab of mobile equipment or from indoor control rooms/activity areas. Some activities are performed outdoors while standing directly on phosphate shale or slag, but workers are typically transported to outdoor activities by light vehicles, such as pick-up trucks.

Most of the dose rates to FMC workers were measured in August, 1994 by IT personnel. Subsequent measurements were made by the FMC Radiation Safety Officer using identical methods and equipment. Sampling location descriptions and measurements can be found in Table 2. Sampling locations are shown on a map (FMC Drawing #399176) attached. All measurements were made in the usual worker geometry, e.g., inside equipment cabs or control room, or standing outdoors. When measurements were made in a shielded geometry, a corresponding measurement was made, when possible, standing at the same location well removed from any shielding device. The shielded and unshielded measurements were compared to obtain shielding factors for the various activities. Table 3 of this report summarizes the shielding factors.

IT measurements were performed with a Bicron µrem meter (B846M), which is tissue equivalent for exposure measurements. The meter was calibrated 5-12-94 and was due for calibration 11-12-94. FMC measurements were also performed with a Bicron µrem meter (B645R). This meter was calibrated 1/31/95 and is due for calibration 1/31/96. These meters were performance checked against several locations that were established in a previous study using a pressurized ionization chamber (IT 1994).

Table 1. Comparison of IT PIC and μrem Meters

Location	PIC* (μR)	μrem** (μrem)
1	16.4	15
2	10.8	10
3	21.0	20
4	55.0	53

*Pressurized Ionization Chamber (does not include conversion of 0.95 μR = μrem).
**All values within 3 standard deviations of PIC (PIC ± 0.7 μR; μrem ± 2 μrem).

Development of Shielding Factors

The usual quantity for radiation risk assessment is excess risk above background. Excess exposure rate, E_E, is obtained from the total exposure rate, E_T, by subtraction of the background exposure rate, E_{BG}, or

$$E_E = E_T - E_{BG}. \qquad 1.$$

The background exposure rate is considered to be inescapable, although this may not be strictly true in all cases. If a shield is sufficiently thick and completely surrounds a point, then the shield becomes the terrestrial radiation background for the point. The cosmic radiation portion of the background cannot be easily shielded and is generally considered to be undiminished except for extremely thick shields. For most outdoor situations, a shielding factor, F_S, is obtained as the ratio of the excess exposure rate in the shielded configuration to excess exposure rate of the unshielded configuration. If the exposure rate in the shield is E_S, then F_S is found by

$$\frac{E_S - E_{BG}}{E_E} = F_S. \qquad 2.$$

That this is the correct expression can be seen from the following:

Outside a shield, the gamma radiation comprises cosmic radiation, γ_c, and terrestrial radiation, γ_t. The cosmic radiation is unshieldable so that

$$(\gamma_c)_u = (\gamma_c)_s. \qquad 3.$$

The subscripts, *u* and *s*, refer to the shielded and unshielded cases. The terrestrial radiation is shieldable, but since the terrestrial radionuclides are found in all materials, the total shield (typically comprised steel, plastics, fabrics, and other materials) is assumed have approximately the same concentrations of terrestrial radionuclides, so

$$(\gamma_t)_u \cong (\gamma_t)_s . \qquad 4.$$

The total background radiation (cosmic and terrestrial), γ_{bkg}, is, therefore, approximately the same for the shielded and unshielded cases,

$$\gamma_{bkg,u} \cong \gamma_{bkg,s} . \qquad 5.$$

It is assumed that phosphorus slag also contains similar amounts of terrestrial radionuclides with the exception that the concentration of ^{226}Ra is higher. It is the ^{226}Ra above background that can be shielded. The above background radiation from phosphorus slag is found by

$$\gamma_{p,a} = \gamma_{p,t} - \gamma_{bkg,u} . \qquad 6.$$

The subscript, *p*, refers to phosphorus slag; *a*, refers to above background; and *t*, to the total radiation from slag.

The exposure reduction factor, f_{er}, for the radiation due to slag is obtained from

$$f_{er} = \frac{(\gamma_{p,t})_s - \gamma_{bkg,s}}{\gamma_{p,t} - \gamma_{bkg,u}} \qquad 7.$$

Substitution of equations 5 and 6 into equation 7 results in

$$f_{er} = \frac{(\gamma_{p,t})_s - \gamma_{bkg,u}}{\gamma_{p,a}} . \qquad 8.$$

Equation 8 shows that the exposure reduction is properly considered for the above-background exposure from slag if a reduction in background is not effected by the shield.

The exposure rate, E_S, at a given, shielded location, is obtained from (EPA 1979)

$$E_E \cdot F_S + E_{BG} = E_S . \qquad 9.$$

The excess, shielded exposure rate, E_{ES}, at any location, using the same shield can be determined using the shielding factor and the total unshielded exposure rate E_T

$$E_{ES} = E_S - E_{BG} = E_E \cdot F_S = (E_T - E_{BG}) \cdot F_S . \qquad 10.$$

Dose at a location, S_i, is obtained as the product of the excess exposure rate, E_{Ei}, and the time at the location, t_i. The total dose, S_T, is the summation of doses at the i locations

$$S_T = \sum_i E_{Ei} \cdot t_i \, . \qquad 11.$$

The total dose must be converted to effective dose before risk can be assessed.

Conversion of Exposure to Effective Dose

For external radiation of any given energy flux, effective dose to any point within an organism depends on the type and energy of the radiation, the depth within the organism of the point at which the effective dose is required, and the elementary constitution of the absorbing medium at that point. The relationship between exposure and effective dose for external radiation is given by:

$$H_E = \Sum w_T H_T. \qquad \text{(Zankl 1992)} \qquad 12.$$

H_E is the effective dose, w_T is the tissue weighting factor, and H_T is the tissue equivalent dose. The spatial distribution of exposure requires modeling of the effective dose in tissue, based on the distribution of the sources of radiation. H_E for several source distributions and energies has been calculated by the ICRP and presented in ICRP 51 Table 3a (ICRP 1987). H_E has also been calculated for a planar source in Federal Guidance Report No. 12 (EPA 1993).

Environmental terrestrial radiation comprises a spectrum of gamma energies ranging from 0 to 3000 keV of both discrete primary energies and degraded energies. These energies are strongly to moderately attenuated in tissue, so there is a large variation in H_E with energy for equal amount of exposure at these energies. Cosmic radiation, also a part of environmental radiation, is usually of much higher energies, which are mildly attenuated by tissue. H_E is nearly 1 for cosmic radiation.

It is necessary to integrate over H_E for all energies of terrestrial radiation in order to obtain an average H_E for calculating effective dose. A typical background radiation spectrum for the area of the FMC Plant was used to integrate over the conversion factors. For a planar geometry the result was $H_E = 0.65$ of the exposure. For a room having walls and a floor as a source, the typical background spectrum yielded $H_E = 0.67$ of the exposure, using a combination of conversion factors for planar and rotationally symmetric sources.

The typical background spectrum includes contributions from uranium, thorium, and potassium. Phosphogypsum has contributions from essentially ^{226}Ra and progeny only. Radium has a lower average energy than the background spectrum, which will cause a slight lowering in the average H_E. The lowering is small enough that it is practical to use H_E of the typical background spectrum.

The portion of effective dose of interest to this study is the above background effective dose. It is necessary to convert exposure to effective dose for this portion only. Calculation of above-background, shielded, effective dose is performed by first calculating the above-background total exposure by equation 11 then multiplying the result by 0.65,

$$H_E = 0.65\ S_T. \qquad 13.$$

This manner of converting to the dose equivalent after subtraction of the background exposure eliminates the need for a conversion that includes the cosmic component.

Conclusions

Based on the data in Table 2, there is no need for a radiation program under 29 CFR 1910.96. A radiation protection program is required where external radiation doses have a potential for exceeding 500 mrem/y. The highest dose rates observed were near 55 µrem/h which, after subtracting a background of 13 µrem/h, yields an excess dose rate of 42 µrem/h. Full-time exposure at this rate for 2000 hrs results in 84 mrem/y. This dose is far below the requirement for a radiation protection program.

The actual doses will be much lower than this maximum dose because full-time is not spent at the highest exposure rates and shielding is present for most outdoor activities. The actual doses should be calculated by equation 11 and a single location annual dose can be calculated by

$$\mathbf{DA_i = (GDR - BG) \times ET \times EF \times SF}$$

DA = annual dose
GDR = total gamma dose rate at a location
BG = background dose rate
ET = exposure time in hours per day
EF = exposure frequency in days per year
SF = shielding factor

The shielding factors must be calculated only for outdoor locations where personnel may be shielded by vehicles. When unshielded, the shielding factor is 1. Shielding factors calculateds from Table 2 are shown in Table 3. The shielding factors are corrected for background.

References

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EPA 1993 **External Exposure to Radionuclides in Air, Water, and Soil**, K. F. Eckerman and J. C. Ryman, Federal Guidance Report No. 12, U. S. EPA, Washington, DC, 1993.

ICRP 1987 **Data for Use in Protection Against External Radiation**, International Commission on Radiation Protection, Report 51, 1987.

IT 1994 **Methods Development Study Report**, September 1994 .

Zankl 1992 **Effective Dose and Effective Dose Equivalent -- The Impact of the New ICRP Definition for External Photon Irradiation**, M. Zankl, N. Petoussi, and G. Drexler, Health Physics, Vol. 62, No. 5, May 1992.

Table 2
Gamma Radiation Measurements
FMC Pocatello, Idaho
(All measurements made with a Bicron μrem meter)

Location (#) = Map Reference	**Shielding**	**Exposure rate** (μrem/h) (Includes background)
(1) Main Entrance Security Office	None - outside	12-15
(2) Burden Business Building	None - outside	25
	Inside pickup cab	18
(3) Shale Stacker	None - outside	45
	Inside pickup cab	32
	None - outside	50
	Inside operator area	30
(4) North of Kiln Bldg.	Inside pickup cab	25
(5) Silica Pile Area	None - outside	10
	Inside pickup cab	10
(6) Dry Valley shale pile	None - outside	35
	Inside pickup cab	25
(7) Reclaim wheel	None - outside	45
(8) Crusher Bldg.	None - outside	38
	Inside pickup cab	22
	None - outside	45
	On steps outside control room	25
	Inside control room	14
(9) Car Dumper, no shale dumping	None - outside	20
	Inside control room	15
(9) Car Dumper, with shale dumping	None - outside	35
	Inside control room	20

Table 2 (continued)

Location (#) Map Reference	**Shielding**	**Exposure rate** (μrem/h) (Includes background)
(10) Briqueting building	None - outside	10-15
(11) Walkway	None - outside	30-45
(12) Kiln building (break area)	None - outside	10
(13) Calciners	None - outside	10-15
	Inside control room	10
	None - outside, near a pallet	20
	None - outside cat walk	15-18
(14) Pallet shop	Inside	10
(15) South side calciner	None - outside - Fines pile	38-45
	None - outside - Fan area	10
(16) Cooling towers	None - outside	15-40
(17) Nodule reclaim	None - outside	45
(18) East end of furnace	None - outside bldg.	10
(19) Tapper cool down	None - outside bldg.	10
(20) Near slag pit	None - outside	20
(21) Furnace Control Rm. 1&2	Inside control room	10
(22) Furnace Control Rm. 3&4	Inside control room	10
(23) Furnace 3&4	Inside-Near tapper break structure	15
	Inside break structure	15
	Inside-Furnace area	25

Table 2 (continued)

Location (#) = Map Reference	Shielding	Exposure rate (µrem/h) (Includes background)
(24) Tapper Area	Inside-Near tapper break structure	15-20
	Inside tapper break structure	15
25) Slag pit, west side	None - outside	35
	Inside #1 Link Belt cab	22
	None - outside	30
	Inside #2 Link Belt cab	20
	None - outside	43 (45-48*)
	Inside slag truck cab	15 (15-17*)
	None - outside	40 (44-47*)
	Inside Cat FEL cab	15 (15-20*)
(26) Slag pile, various locations	None - outside	52
	Inside pickup cab	22
	Inside slag truck cab	15
(27) Outdoor fabrication area	None - outside	25-30
(28) Phos tank cleaning area	None - outside	35
	None - outside on platform	20
	Inside control room	10
(29) Contractor Gate	None - outside	33*
	Inside guard shack	23*
(30) Ponds	Inside shack	20*
(31) Ponds	None - outdoors, near pump station	37*

* These measurements were taken by the FMC Radiation Safety Officer with a Bicron µrem meter (B645R. The meter was performance checked at several locations where levels were established by IT using a pressurized ionization chamber (IT 1994).

Table 3
Calculated Gamma Radiation Shielding Factors
FMC- Pocatello, Idaho

Shield	Shielding Factor (1)	Work Area	Map Location
Pickup cab	0.58	Burden Business	(2)
Pickup cab	0.41	Shale stacker area	(3)
Pickup cab	0.54	Silica pile area	(5)
Pickup cab	0.45	Dry Valley shale	(6)
Pickup cab	0.64	Crusher building area	(8)
#1 Link Belt cab	0.59	Slag pit	(25)
#2 Link Belt cab	0.59	Slag pit	(25)
Slag truck cab	0.93	Slag pit	(25)
Cat FEL cab	0.93	Slag pit	(25)
Pickup cab	0.77	Slag pile area	(26)
Slag truck cab	0.95	Slag pile area	(26)
Average	0.77		
SD	0.26		

(1) The factor reported above is $1-E_{ES}$, where E_{ES} is the excess, shielded exposure rate calculated from Equation 10 (given earlier in this report).